OUR ENVIRONMENT
HOW TO USE AND CONTROL IT

WOLF AND CARPENTER

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MODERN SCIENCE SERIES

Irwin A. Berends

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PLATE I.—OUR OUTDOOR ENVIRONMENT.

How many different things can you find above which make up our environment (see section 1)? How many are useful to us? How and why are they useful?

Modern Science Series for Junior High Schools
EDITED BY JAMES M. GLASS

BOOK III

OUR ENVIRONMENT

HOW WE USE AND CONTROL IT

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PREFACE

This text is an *organized study* of *our environment*, for beginners in science. It has seven major aims: (1) to increase the pupil's *appreciation* of the factors of his *environment;* (2) to develop his *powers of observation;* (3) to train him in the *scientific method;* (4) to stimulate him to *organize his common experiences* for use in the solution of new problems; (5) to help him form *right habits;* (6) to develop his desire to practice *personal hygiene;* and (7) to teach him the specific ways in which the principles of science are applied to the *work of the world* so that he may fully realize the importance of science in the home, community, state, nation, and the world at large.

Since activity is a fundamental characteristic of the early adolescent, observations, problems, experiments, and projects must be *dynamic.* Fortunately, air, water, heat, light, and electricity are all active. They interact and seem to enjoy activity just as the adolescent enjoys active living. They are coördinated through *energy and work* and their activities are the results of this coördination. Through a study of their activities as factors of his environment, the pupil can *organize* a *knowledge* of his *environment* according to his natural interests. He sees his surroundings as a *dynamic* whole. Thus environment supplies the cue for the selection of materials, while energy furnishes a cue for the method of study of general science.

The all-embracing goal of the study of science is to give the pupil an *overpowering curiosity and desire to know the truth.* If he can understand the principles and the labor involved in the discovery and perfection of man's appliances for the

control of energy and matter, he is in a position to feel that he is intimately related to the work of the world and that he may some day make a valuable contribution to the promotion of happy living.

PLAN OF THE BOOK

In general the plan of this book is to develop materials and methods of study in logical sequence through Parts I to VIII. The plan of each part is given below.

Part I: Environment, Energy, and Work. The pupil is introduced to his environment. He learns its meaning and importance, and some of the laws controlling it. He begins the process of generalization.

Part II: The Work of the Factors of Our Environment. Here the pupil is taught to observe the factors of his environment at work for man in the home and community. Observations, demonstrations, and experiments give him the first dynamic aspects of the study of science.

Part III: The Importance of Industry. Energy is shown to be the link which connects environment with the work of the world. The pupil will take keen interest in the dynamics of manufacturing, agriculture, transportation, communication, and other vocational activities.

Part IV: The Source of All Energy. The fundamental fact is here developed that the sun is the source of all energy; that industry, the weather, and the work of the home are all dependent upon the sun.

Part V: The Storage and Use of Solar Energy by Living Things. The transition from the inorganic to the organic aspects of environmental study is made by investigation of the process of storing up solar energy in the form of food, in the products of farm, ranch, and garden.

Part VI: The Work and Care of the Human Body. The pupil learns here that the human body is an engine run by the conversion of solar energy into muscular energy through the

medium of food. The proper care and development of the engine and its engineer (the brain), through the formation of right habits, are emphasized as vital factors of self-improvement.

Part VII: The Work of Protecting the Human Body from the Dangers in Its Environment. The invisible foes of the body which are present in air, food, and water, are revealed through experiment and discussion. The pupil studies disease prevention and learns that its beneficial results are a product of the scientific method.

Part VIII: The Work of Improving Living Things. This last division shows that the continuation of man's control of his environment depends primarily upon his control of the quantity and quality of plants and animals, and upon the improvement of man himself.

SPECIAL FEATURES

Characterizing all of the above parts are the following special features:

1. An *Introductory Chat* occurs in a box of bold-face type at the beginning of each chapter. It gives a proper approach to the work of the chapter by its challenge to the pupil's present fund of knowledge.

2. *Practical Questions* focus the pupil's attention on the work of the chapter and recognize that he is already in a position to contribute something to the subject.

3. *Home and Field Problems* present a concrete articulation between home, community, and school activities. They help the pupil see that his science is of a practical nature and furnish him with practical applications of the information gained in science work.

4. The *Conversational Style* makes the pupil feel that this book was written especially for him. Definitions are written with a view to objectifying the ideas they present. Many statements which, from the standpoint of pure science, may

seem incomplete are justified by pedagogical considerations for the mind of the ninth-year pupil. The effort has been to avoid abstract or technical terminology by use of simple yet adequate wording.

5. *Key Words* are found at the ends of the first five chapters, with provision for their development thereafter. They offer a splendid background for review work. As an oral exercise, their exact meaning may be brought out in short sentences or paragraphs, thus supplying excellent drill in the formation of general concepts.

6. The *Review Outline* is to be used in the way its name implies. Topics may be assigned and elaborated in oral or written exercises.

7. The *Summary* is a condensed story of the chapter. Every sentence is a theme for elaboration in oral or written work. Topical words and phrases are here italicized for ready reference.

8. The *Thought Questions* test the ability of the pupil to apply his science to new situations.

9. *Special Problems* throughout the book and in the appendix present the fundamentals of project work.

10. *References* have been selected with special regard for the interests of the ninth-year pupil.

11. *Demonstrations* are numerous. Twenty-eight of them are marked as *Keys* because they are especially important units in the organization of the subject matter. They focus discussion and develop the scientific attitude of mind. All Key Demonstrations are to be entered in the pupil's Science Discovery Book. Directions are given on pages 5 and 35 which will produce a fairly uniform set of such entries, thereby lightening the work of pupil and teacher.

12. *Suggested Experiments* supplement the Key and other demonstrations, serving as original tasks in the home or school.

13. *Illustrations* are based on the belief of the authors that every picture should (1) increase interest in science;

(2) amplify and interpret the text; (3) present a real problem for study; and (4) be clear and easy to understand. Five types of pictures appear: (1) (*Key*) *Demonstration* pictures guide the pupil in assembling apparatus, though in no case are processes detailed. (2) *Subject Matter Illustrations* were selected for their clearness. Beneath each is an explanation or a series of questions requiring close study of the picture. (3) *A Key Picture* introduces every chapter and incorporates its leading ideas. It is to be used constantly as the chapter is studied. (4) The *Biography Pictures* with their legends add an intimate human touch. (5) The *Colored Plates* feature generalized problems which coördinate the major units of the book.

ARTICULATION OF THE TEXT WITH THE *MODERN SCIENCE SERIES* AND WITH THE SPECIAL SCIENCES

This text aims to adapt the work to the needs, interests, and previous training of the ninth-year pupil. It is a self-contained treatment of general science but at the same time it preserves the continuity of development in the three books of the *Modern Science Series*. While it is an accumulative text in its own series, it is especially designed as an independent and comprehensive book in general science for either the third year of the Junior High School or the first year of the Senior High School.

From the first chapter to the last there is a gradual sequence of topics, fitted to the understanding of the ninth-year pupil through use of the inductive-deductive method. Constant reference and application to the central theme, man's use and control of his environment, have produced a unified treatment of the special sciences. Their special applications are presented in a fashion suited to the needs and capacities of the ninth-year pupil, thus preparing him for the next steps in his science work, the studies of biology, chemistry, physics, physiography, and other special sciences.

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G. C. W.
H. A. C.

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Come forth into the light of things,
Let Nature be your teacher.

— WORDSWORTH

MODERN SCIENCE SERIES
BOOK III

KEY PICTURE 1. — OUR INDOOR ENVIRONMENT.

The many things surrounding the man in this picture are all *immediate* factors of his environment. Which are necessary to his existence? Which are not? This picture serves as a key to Chapter I.

OUR ENVIRONMENT

HOW WE USE AND CONTROL IT

PART I

ENVIRONMENT, ENERGY, AND WORK

CHAPTER I

SCIENCE AND LIFE

1. What You See about You

Knowledge advances by steps and never by leaps. — *Macaulay.*

1. **Your Surroundings.** — Every bit of knowledge which you possess has come from your surroundings. How do you know what the wind is? or the rain? or the sun? Did this knowledge come from within yourself? Consider any six objects with which you come in contact every day. Where are they? They are found in your surroundings. The things which surround you, things which you can see, feel, hear, smell, taste, or know in any way, make up what is called your *environment*. Environment, then, consists of the surroundings in which you live.

You come in close touch with these surroundings every moment of your life. The character of your daily activities, such as eating, drinking, sleeping, playing, and working, depends on your relation to your environment. This holds true whether you live in the country or in a crowded city. All the problems of your life, then, have to do with

your relation to light, heat, and electricity, and to water, air, soil, food, and other substances of different kinds. These things we call the *factors* of your environment (Key Picture 1).

1. Name five factors of your environment which are of importance or value to you and tell how they are important or valuable.

2. Make a list of ten different ways in which our environment is used every day to help us carry on our work.

3. Make a list of all the factors of the environment you can discover in the frontispiece.

FIGURE 1. — THE ENVIRONMENT OF LIVING THINGS.

How many living things are in this picture? In what ways are their environments the same? Do they all need the same things in order to live? How are they fitted to use those factors of their environment which keep them alive?

4. Make a list of several facts you already know about the factors you have named.

5. Add to this list of facts any others you may be able to find in a dictionary about each of the factors you have named.

6. Make a scientific statement about any six factors, including all of the facts you have collected about them. Copy these statements in your Science Discovery Book (see opposite page).

2. Environment and Life. — If you classify the factors of your environment in a scientific manner you will find that they form two groups: (1) those necessary to life, and (2) those which are not necessary to life. Long before man knew anything about the use of coal, or electric lights, or the value of steam, he needed *water* to drink, *food* to eat, and *air* to breathe. Thus some of the factors of your environment are absolutely essential to your existence and to every other living thing. (What factors are necessary to the

YOUR SCIENCE DISCOVERY BOOK

As you study your environment you will make a good many discoveries. You will see things new to you and will look at familiar objects in a new light. You will find pictures in magazines or come upon newspaper clippings which will appropriately illustrate your discoveries. Where can you put all these interesting things? What better place could possibly be found in which to enter your observations and record your discoveries than in your Science Discovery Book?

And what is this Science Discovery Book? It is a note-book uniform in size and quality with the others in the class. Whether you buy it or whether your school issues it to you, let it be your own, your personal possession, devoted entirely to your observations, discoveries, experiments, special problems, reports, readings, and drawings, and to the pictures you collect. It will also contain your Key Word stories (p. 23) and your Review Outline compositions. You will really build little by little a text-book of your own, just as the author has built this book.

Spare no effort or time in making your Science Discovery Book the finest book in your class. Make it as neat, as attractive, as scientific, as complete, and as beautiful as you possibly can. It will be a source of satisfaction and pleasure to you as you study science.

man in the Key Picture?) You should be greatly interested in finding out all you can about these factors.

Can you imagine what life would now be without the automobile, the steam locomotive, and the electric car? Yet the writer of this paragraph was as old as most of the boys and girls who read this book before electric lights and trolley cars were used. Indeed, the first successful automobile in the United States came into use no longer ago than 1898.

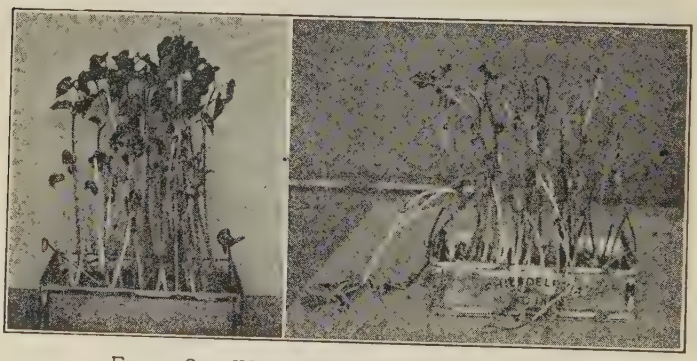


FIGURE 2.—WATER IN ITS RELATION TO PLANTS.

The bean seedlings at the left had plenty of water. The same seedlings at the right ten days later. What made the difference? Explain.

To see *relations* between the factors of environment is the real basis of discovery and invention, as well as a source of much pleasure. Suppose you try to discover some of these relations.

Now look at the frontispiece and answer the following questions about it in your Science Discovery Book.

1. Name all the factors you can see in the environment here pictured which are important (*a*) to the people; (*b*) to the animals; (*c*) to the plants; (*d*) to the insects; (*e*) to the birds.

2. Which of these factors are necessary (*a*) to the people; (*b*) to the insects; (*c*) to the plants; (*d*) to the birds?

HOW TO PRONOUNCE

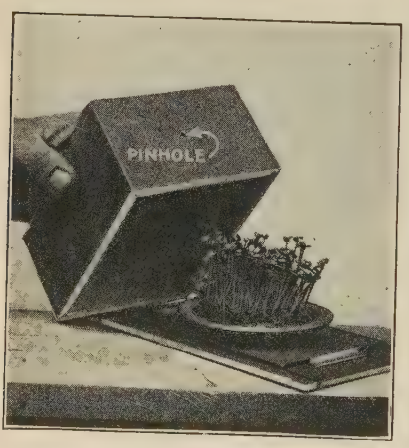
All the words in this book which may be hard for you to pronounce are marked. By following the sounds indicated below you should be able to pronounce any of such words without the least trouble. The pronouncing scheme here used is that found in Webster's dictionary.

ā as in *āle;* ȧ as in *senȧte;* â as in *câre;* ă as in *ăm;* ä as in *ärm;* ȧ as in *sofȧ.*
ē as in *ēve;* ė as in *ėvent;* ĕ as in *ĕnd;* ẽ as in *makẽr.*
o͞o as in *fo͞od;* o͝o as in *fo͝ot.*
ī as in *īce;* ı̆ as in *ı̆ll.*
ō as in *ōld;* ȯ as in *ȯbey;* ô as in *ôrb;* ŏ as in *ŏdd.*
ou as in *out;* oi as in *oil.*
ū as in *ūse;* u̇ as in *u̇nite;* û as in *ûrn;* ŭ as in *ŭp.*
zh as in *azure.* g as in *go.* ŋ for the *n* in *bank.*

3. Environmental Factors Differ in Their Importance to Living Things. — Your previous study of science has no doubt proved to you that while all animals and plants must use certain factors of their environment in order to live, yet these factors vary in their value to and use by living things. Fish, for example, live in the water and can live nowhere else. Land animals, on the other hand, such as the dog and the horse, would soon die if kept under water. They must breathe free oxygen (ŏk′sĭ-jĕn) through their lungs. All green plants need light in order to grow (Fig. 3), but other plants, such as mushrooms, will thrive in a dark cellar. Some plants need little light. Others, such as roses, need much light. All animals and plants (Fig. 2) must have water, but some need it in greater amounts and more frequently than others. The camel, for example, can go for many days without a fresh drink of water, but man can live only a very few days without it. Some of the lower animals can exist weeks and even months without contact with moisture. Some insects do not like light and run away when exposed to it.

Moths and birds are attracted to it. Mice live in walls without light. Polar bears live in regions of little heat, while alligators live in hot, tropical regions. To most plants soil is necessary, but some float free in the water and others seem to grow upon bare rock. Study Figure 4 and answer all questions on it.

4. How Environment Affects Living Things. — Each animal lives in a different environment and seems to be in some



Popular Science Monthly.

FIGURE 3. — LIGHT AND LIFE.

An experiment which proved the extreme sensitiveness of mustard seedlings to light. Covered by a box into which candlelight was allowed to filter through a pin-hole, the seedlings after five minutes were found to be leaning toward the source of light, as shown at the right.

Do you think light is a necessary factor in the environment of plants? Can you explain this?

way *fitted* (*adapted*) *to the environment in which we find it.* It gets along in its home region with little difficulty.

The body of a fish is shaped to move easily through the water. Its fins are fitted to propel it; its gills, since it cannot use lungs, take free oxygen out of the water; its body is covered with scales and slime; its eyes are adapted to seeing nearby objects only (Fig. 5).

The bird, on the other hand, has hard, very strong bones, adapted to flight. It has a body well-shaped to cleave the

FIGURE 4. — WHERE LIVING THINGS LIVE.

1. What would you put into each picture as a background to show what the natural environment of each would be?

2. What is there about each of the living things in these pictures which makes you think that the environment you select for each is correct?

3. Which of the factors of the environment of each are necessary? Which are not necessary? How and why do these factors differ in the different pictures?

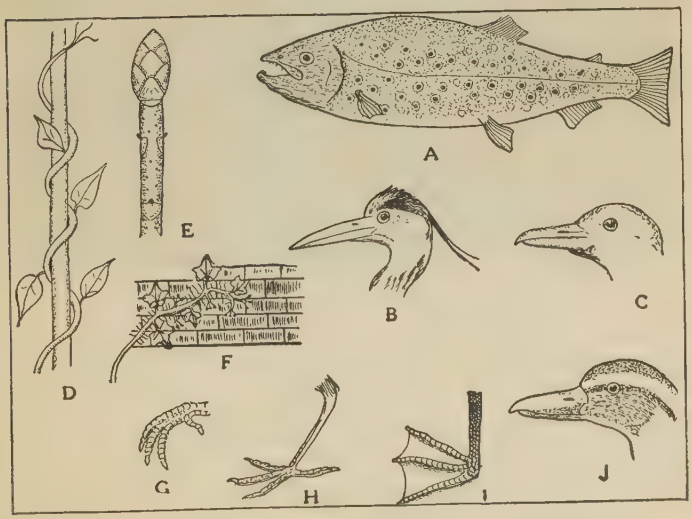


FIGURE 5. — ADAPTATIONS TO ENVIRONMENT.

How many different adaptations to environment can you find in this picture? List all of them and opposite each give the factors of the environment and the use of the adaptation.

air; feathers which well protect it; eyes fitted for seeing in all directions; feet fitted for perching, walking, wading, or swimming (according to the type); and a bill fitted for securing the food found in its natural environment (Fig. 5).

In Brazil most plants have large, broad leaves, thin, climbing stems, and shallow roots (Fig. 6). The plants of

FIGURE 6. — HEAT, MOISTURE, AND LIFE.

What is the advantage of the large leaves? What two conditions are favorable to the growth of such leaves? Would such leaves ever be a disadvantage to the plant?

the Arizona desert have thick, sturdy stems covered with sharp spines (reduced leaves), and long, stout roots (Fig. 7). Cotton plants will not grow far north nor will wheat thrive in the southern states. Ostriches cannot live in Canada nor elk thrive in the Sahara desert. All this seems to show that animals and plants are limited to a certain locality and cannot move from that locality without fatal results. The one ex-

ception to this rule seems to be man. He can pass all barriers; live in cold or hot climates; in high or low altitudes, all because he knows how to take proper care of himself and can largely control his environment.

5. How Living Things Affect Their Environment. — The ancient plagues of Egypt were caused by hordes of insects

FIGURE 7. — HEAT AND LIFE.
What is lacking here that was present in Figure 6? What causes the difference? Explain.

which ate up the vegetation and caused famines. Grasshoppers to-day in some parts of the United States completely change the environment by destroying millions of dollars worth of crops. The annual loss in this country due to insects is $1,500,000,000 (one billion, five hundred million dollars). Mosquitoes in South America and Central America have driven out whole populations because of the yellow fever which they carry. The army worm destroys masses of vegetation in a few days.

Wide World

FIGURE 8. — FOREST DESTRUCTION.

One way in which man changes his environment. What are the advantages and disadvantages of such changes?

Man, himself, is probably the greatest factor in changing or affecting the environment. He has utterly destroyed the passenger pigeon (Plate II). By the destruction of forests through cutting (Fig. 8) and fires, birds are driven out, insects increase, and crop destruction follows. Floods are more frequent, soil is carried away, and farms suffer. On the other hand some of man's changes have been beneficial. The irrigation of desert lands in the West and the draining of swamps in the South have made new and valuable regions. Note the following news item:

> Cape Girardeau, Mo., Dec. 2, 1924. The world's greatest drainage reclamation project is now nearing completion at a cost of $50,000,000. Nearly 3,000,000 acres of swamp land in southeastern Missouri and northeastern Arkansas will now be tillable. Worthless lands now become worth $40 to $100 an acre. Corn, wheat and cotton will be raised on this reclaimed land. The mosquitoes have been driven out, malaria has disappeared and homeseekers are pouring in by the thousands.

No better example could possibly be given of man's control over his environment. How did man change the environment when he built the Panama Canal? How did this change affect the whole world?

PLATE II.—THE PASSENGER PIGEON.

This beautiful bird once existed in such large numbers that its flocks darkened the sky with their passing. It is now extinct. Man, wild animals, and perhaps disease brought the species to an end.

A few years ago the Cincinnati Zoo possessed a living specimen for which every effort was made to find a mate, but without success. The bird's death stopped further search.

Examine the frontispiece for the second time and write out in your Science Discovery Book the following:

1. At least one way in which each of the living things you see in this picture may affect or act upon its environment.
2. At least one way in which the factors of the environment may affect or act upon the living things in this picture.

6. Man's Natural and Artificial Environments. — As a savage, man lived simply, with little or no clothing, little or no shelter, scant and poor food, and no comforts whatever. This was man's *natural environment.*

But the time came when man began to *think.* He began to make the forces of nature and the factors of his environment actually *work* for him.

As man learned more facts about his environment, he built villages, bought and sold produce and skins of animals, learned trades, developed business. Cities followed with business buildings, railroads, steamships, bridges, apartment houses, churches, and schools, until now the forests are fast disappearing. Man now lives in an *artificial environment,* — one made by his own brain and hands. He now lives in an *age of science.* His study of his environment has added many comforts to his life.

1. Make a list of several ways in which man affects his environment.
2. Now make a list of the ways man's environment affects him.
3. How do you learn new facts about your environment?

But with this artificial environment have come advantages, dangers, and problems. For example: an advantage of city life is increased comfort; a danger of city life is epidemics of disease; while a problem of city life is the securing of a sufficient supply of pure water or the proper disposal of sewage and garbage.

1. Make a list of five advantages of town and city life.
2. Make a second list of five dangers of city life.
3. Make a third list of five problems of city life.

Copy the above in your Science Discovery Book for future reference.

7. Environment and Work. — Enough has already been said to show you that man is continually moving the factors of his environment about. This requires effort which in turn means *work* and plenty of it. It seems that the *first law of nature is work*. All the forces of nature are hard at work. All living things work. Man is no exception to this rule.

FIGURE 9. — IN THE YOSEMITE VALLEY.

Both an artificial and a natural environment are here shown. Explain. Would this forest be found in either of the environments illustrated by Figures 6 and 7? Explain.

Men must cut trees into logs with tools and then cut these logs into lumber, if furniture and houses are to be made. Men press clay into bricks and put these bricks into the walls of schools and churches. Stones are cut from the quarry and libraries are built from these stones. Wool is taken from the sheep and clothing is woven from this wool. Seeds are planted in the ground and whole nations are fed with the wheat and corn grown from these seeds and harvested by the work of men.

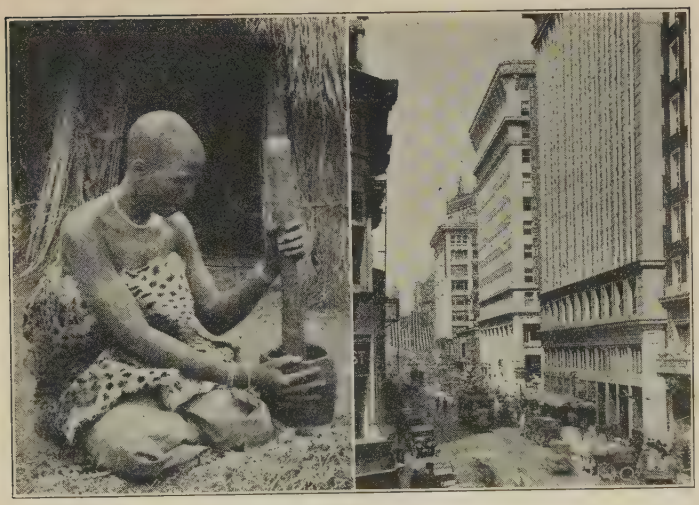


FIGURE 10. — COMPARE THESE TWO ENVIRONMENTS.

What factors are alike? What are different? What made the vast difference in the two scenes? Explain fully after reading sections 6, 7, and 8.

8. Man, Then, Is a Working Animal. — Almost every week we read in the newspapers of new discoveries and new inventions which use the factors of our environment. To make such discoveries for the good of the greatest number of people is the work of *scientists* and *this work is science.* Because we live in the age of science we also live in the age of *work.* All helpful activities we call the *world's work.*

Now look again at the frontispiece and answer these questions about it in your Science Discovery Book.

1. Make up a list of ten questions which you might ask about this environment which can be answered by a study of the picture. For example: Does the temperature stand at a high, medium, or low point?

2. What factors in this environment are used by man to help him in his work?

2. How You See about You

9. How We Learn. — How do we learn what we know? We learn about the factors of our environment by the use of our *five special senses — sight, hearing, touch, taste, and smell* — sometimes called "the windows of the soul." We know that sandpaper is rough; that a rose is red; that a lemon is sour; that a clanging bell produces sound; and that an orange gives off an odor. It is true that some of our senses, especially those of sight and hearing, are more keen than the others, but we learn through the use of all of them and the result is *knowledge*. And *knowledge is simply that which has been or can be learned.*

But knowledge alone will not make us happy, good thinkers, or successful. It is what we do with our knowledge that counts. To make knowledge worthwhile we must put our facts together in such a way as to make them of the greatest use to us. To make the best use of our knowledge it is necessary to study science.

Once more, looking at the frontispiece, tell

1. Which of these factors are natural and which are artificial.
2. Which of these factors can be known by the eyes, which by the sense of touch, which by the hearing, which by smelling, and which by tasting.
3. What devices are shown in this picture which have been produced by the thought of men?

10. Knowledge and Signs. — All savage tribes believe in "signs." They are always trying to escape from evil spirits which they believe exist to injure them.

All our own remote ancestors believed in evil and good signs. They planted their crops during the new moon because a "growing" moon makes things grow.

As people gained knowledge they began to lose these foolish beliefs. To-day educated people do not believe in "signs" because signs have absolutely no relation to science.

11. Science Defined. — Ice is cold, and it has existed in the world for untold ages, but for centuries no one knew that it would preserve food. Had this been known before the

© *The Franklin Foundation.*

FIGURE 11. — FRANKLIN'S EXPERIMENT WITH THE KITE.

What factors of his environment is Franklin using here? What materials is he using? How do you know that he is experimenting? Did Franklin believe in signs? Was Franklin a scientist? Explain. What discovery did he make here? How did he make it?

year 1492 it is probable that America would not have been discovered for many years, for Columbus was seeking a western passage to Asia to bring back spices to be used in preserving foods. To-day, we keep foods for days in ice boxes and in refrigerator cars, — in cold storage plants for months. The same can be said about the uses of salt. Electricity has been in the clouds for ages, but it was

Franklin who first discovered that it was the same as that found on earth (Fig. 11) and Faraday, an English scientist, was the first to show us that it might be used to do work for us.

It is by science that new discoveries and inventions are made. (What is meant by a discovery? an invention?) *Science, then, is knowledge upon any subject so arranged or classified as to be useful to one who desires to use it. Science is classified knowledge.*

Now make a final study of the frontispiece and answer these questions about it.

1. Make a list in your Science Discovery Book of ten scientific statements about the environment you see in this picture.
2. Explain in five different ways how the factors of the environment (including the living things here shown) depend upon one another.

12. Why We Study Science. — This question is often asked: Of what good is the study of science? The answer is: We should study science because we live in an age of science. Everything that we eat, wear, or use to shelter us is the result of long years of scientific experiments.

The writer can well remember when there were no phonographs, automobiles, airplanes, fireless cookers, radios, submarines, skyscrapers, gas engines, electric lights, trolley cars, or bicycles. He can remember when there were no vacuum cleaners, electric irons, electric washing machines, electric fans, motor-cycles, concrete pavements, wireless telegraphs, typewriters, adding machines, safety matches, gas mantles, and many other inventions which he in one short lifetime has seen develop into almost necessary factors of our environment.

Scientific knowledge aids us in work about the house. It helps us to repair leaking faucets, the electric bell, the

smoke pipe of the furnace, the lock on the door, the gears of the lawn mower. To keep our bodies clean, our clothes clean, our drinking water pure, and our sewage from causing disease requires a knowledge of science. We must study and know and practice science in order that we may live successful lives. Surely this alone is a good and sufficient reason for studying science.

13. How We Study Science. — There are many ways of studying science, but some are more common and better than others. We shall mention four ways here and give them to you in the form of stories. Read them carefully and be ready to ask and answer questions upon them and to determine which way is the best, with your reasons.

Story 1. Two boys, Charles and Edward Stewart, were having a lively argument over the question as to what is the highest mountain in the United States east of the Mississippi River.

"The highest mountain is Mt. Marcy or Mt. Washington, I don't know which," declared Charles.

"You are wrong," replied Edward with much emphasis, "Mt. Mitchell down in North Carolina is the highest one."

"That isn't so," returned Charles.

"It is so," replied Edward hotly.

"Well, how do you know, I'd like to know," asked Charles, a little doubtful about his own claims.

"Saw it in the atlas, that's how," returned Edward with confidence, "and I'll show it to you to prove I'm right."

They got the atlas, found the list of mountains with their altitudes and there it was: Mt. Marcy 5379 feet; Mt. Washington (Fig. 12) 6286 feet; and Mt. Mitchell 6711 feet. That ended the argument. Can you explain why?

Story 2. Two girl friends, Margaret and Louise, while spending the evening together, decided to make some candy. Margaret, in doubt as to how to make fudge, looked for her mother's cookbook but she could not find it.

"Never mind, Margaret," said Louise, "I can make some without the cookbook. I know a good recipe."

"Where did you get it?" asked Margaret.

"I really don't remember," replied her companion, "I made it up as I went along and it's easy now, I've done it so many times."

Louise began to pour out the sugar while Margaret watched with some doubt as to her friend's ability to make candy without following closely a printed recipe.

"You're using too little sugar, Louise," suggested Margaret.

FIGURE 12. — MT. WASHINGTON, TAKEN FROM INTERVALE, N. H., AT SUNRISE, IN FEBRUARY.

Name the factors of the environment shown here. Snow remains on this mountain until July. Can you tell why?

"Not a bit. It will come out all right. I've tried it a good many times and now I know."

This statement closed the discussion. The candy was made and was delicious; it proved that Louise knew what she was talking about. Can you explain why her candy was good?

Story 3. Two schoolmates, Robert and Doris, were asked this question by the science teacher: How many legs have insects? Neither could answer the question and they were advised to bring in a report on it the next day. On leaving school that day both began a

dispute as to how many legs insects really did have. Robert said they had four legs. Doris declared they did not have that number, but she would find out.

"How are you going to find out, I'd like to know?" said Robert.

"That's easy," replied Doris, "catch an insect and count his legs."

So they caught a grasshopper and carefully observed him. They found six legs. But this observation did not satisfy Robert. He was beginning to think like a scientist.

"But that doesn't prove anything about all insects, Doris. All grasshoppers may have six legs, but all insects may not have the same number. How are you going to find that out?"

"That's easy again," said Doris with confidence, "catch more insects."

They then caught a housefly, a croton "bug," a beetle, a butterfly, and an ant. Observation showed that every one had six legs. So far as their observations went they were pretty safe in saying that insects as a class have six legs.

They went back to the classroom next day with confidence and gave the teacher the results of their investigation. Why were they so confident?

Story 4. John Stevens and Mary Evans, two schoolmates, were studying science together. They got into an argument as to which weighs the more, copper or iron. John claimed that iron weighs more than copper. Mary was sure that copper weighs more than iron.

"I know iron is heavier," insisted John. "Just think of the iron rails in a railroad track. They have to be heavy."

"But we have a copper kettle at home and that is heavy, I can tell you," returned Mary.

"Pshaw! That's no proof," retorted John, "you probably were carrying it full of something. I want proof. Thinking a thing is so doesn't make it so."

"But you thought that iron was heavier. How can you prove your iron is heavier, I'd like to know?"

"That's easy," replied John, "just weigh them."

So when they got to school John got a piece of iron and a piece of copper and began to weigh them.

Mary stopped him with the remark, "That is no way, John; you must have pieces of equal size in order to prove which one is heavier. I know now more about finding out things than you do."

So they cut off two pieces of iron and copper rods of the same length and diameter and weighed them on the scales. *The copper weighed more than the iron.* John became very quiet. He had nothing to say. The argument was settled. How and why was the argument settled? Explain how both John and Mary knew that the point was settled. Explain why Mary insisted that the pieces of iron and copper be of exactly equal size.

14. How We Discover Scientific Truths. — Charles and Edward settled their dispute by reading facts in a book. They took it for granted that the *authority* from whom they got their facts was correct. You will depend upon the writer of this book for many facts. He depends upon other people for some of his facts.

Louise had learned to make candy by *experience.* Sometimes she no doubt failed, but "practice makes perfect."

Again, Robert and Doris got their information by *observation.* But Mary and John got their facts about iron and copper by an *experiment.* This is a way of getting knowledge that is new to most boys and girls of your age. This method is the very best because you yourself find out something by actually doing something.

Some one learned by experiment that air has weight; that bacteria cause disease; that plants grow best in sunlight; and that electricity may be used to produce heat, light, and power. And all of these things are true for all time. To discover these great truths is the most important work of science.

The following diagram may help you to a clearer idea of the relations and relative importance of the factors of your study. Try to fix the scheme in your mind as a guide to your future work.

Facts you are told
Observations you make
Experiences you have
Experiments you perform
} with conclusions { all increase your knowledge, help you to think straight, and help you to solve new every-day problems.

Why is the last factor — experiments you perform — the most important?

SOMETHING FOR YOU TO DO

Below you will find a list of words which should be of great help to you in the study of science. We shall call them KEY WORDS because they will serve to unlock the storehouse of your mind and let out the ideas held prisoners there.

When you have completed a chapter, begin the study of these words, trying to recall to your mind what they mean to you. For example, take the word "signs." Turn this word around in your mind and see what happens. Does the word mean anything to you? If not, it was never a key to you when you first read it. Turn back to the page where the word is used and read about it again. Does it bring to your mind a clear picture of savage peoples? Do you at once think of some peculiar beliefs of people you know? Could you write a sentence or two about the word "signs" as it is used in this book? Could you enlarge these sentences into a little story about peculiar beliefs of people? Try this and write it out in full in your Science Discovery Book. If you will do this with the other words in this list, especially those which are starred *, you will have a fine basis for a review of the whole chapter.

KEY WORDS

Age of Science*
Arizona desert
artificial environment*
authority*
Brazil
camel
Columbus
discovery*
Egypt
environment*
experience*
experiment*
factors*
Faraday
Franklin
gills
hollow bones
invention*
knowledge*
mosquitoes
natural environment*
observation*
passenger pigeon
polar bears
science*
scientists*
signs*
surroundings*
world's work*

A NEW TEST OF YOUR MIND

If you have written out your Key Word stories in proper form, you are now fully prepared to take up the study of the Review Outline of this chapter. Study topic 1, especially the heading: Your Surroundings or Environment. Try to picture in your mind just what this means. This is a larger key to unlock a whole flock of ideas from your mind. If you find it hard to bring back the thoughts you once had about this topic, look at the three sub-topics. These should help you to remember the whole story. You will find this excellent review work.

After you have thought about the ideas in this whole topic, write a story about them in your Science Discovery Book. After this is done, try topic 2 in the same manner. If you can write a story about each topic without constantly referring to the text-book for help (pages 1 to 22), you have become familiar with the most important thoughts of the whole chapter. No one can take these ideas away from you because they are *yours*. You have gained in knowledge and the power to use your mind. You are beginning to be a real scientist.

REVIEW OUTLINE

1. Your Surroundings or Environment.
   - Definition of environment.
   - Factors of your environment.
   - Your environment, the source of your knowledge.
2. Environment and Life.
   - Factors necessary to life.
   - Factors valuable in making life better.
   - Seeing relations between factors gives us general truths or laws.
3. Environmental Factors Differ in Importance: to plants; to animals; to man.

4. Relation of the Environment to Living Things.
   Plants, Animals, Man } are all fitted to their environments.
   Man largely controls his environment.
5. Relation of Living Things to Their Environment.
   Insects destroy crops.
   Mosquitoes cause the migrations of whole populations.
   Man permanently changes his environment and controls most other living things in his immediate environment.
6. Man's Natural and Artificial Environment.
   His early natural environment.
   His present artificial environment.
7. Man, Environment, and Work.
   Forces of Nature work.
   Plants and animals work.
   Man works by moving about the factors of his environment, thus becoming a working animal.
8. Knowledge of Your Environment.
   How gained.
   Value of the five senses.
   Use of knowledge gained by use of the senses.
9. Knowledge and Signs.
   Knowledge gained by a correct use of the five senses.
   Superstition due to little or no use of the five senses.
10. Science.
    What it is: classified knowledge.
    Why we study it: because (1) we live in the age of science; (2) it lengthens our lives; (3) it gives us comforts; (4) it has given us all our great inventions and discoveries.
    How four boys and four girls studied science: by reading about facts (authority); by experience; by observation; by experiment.

SUMMARY

The world in which we live is our environment, composed of many factors (light, heat, water, food, soil, etc.). These factors we constantly see and use every day. Some of them are necessary to life (air), while others are not (automobiles), but all affect our daily work and pleasures. These factors differ in their importance to different living things (water to fish, air to man). Living things thus seem to be fitted to their environment and cannot well live out of it. Man is the only apparent exception to this rule.

Living things change their environments, some for a short time, others for a longer period. Man is the only animal that has much control over its environment. Because of this man has made himself an artificial environment (cities) and has become a working animal.

Man has succeeded in the use of the factors of his environment because he has learned to use his five senses in gaining knowledge which he has so arranged as to develop it into *science.* We can all learn to be scientists in our everyday affairs by reading, by experience, by observation, and by experiment.

Remember that:

1. Our environment consists of our surroundings.
2. The factors of our environment are not equally important to us.
3. Environment acts upon living things and living things act upon their environment.
4. The work of man consists of moving the factors of his environment about or changing them.
5. Science is the arranging of the knowledge of our environment in such a manner as to get work done easily, quickly, and well. Science gives us a common-sense method of doing work.

THOUGHT QUESTIONS

1. Show how a farmer, a business man, a city dweller, and a miner control their environments.
2. Show how environment may affect the farmer, the sailor, and the town dweller.
3. What kind of men have little control over their environment? What kind have great control over their environment?
4. Make a list of as many living things as you can think of which live in your environment.
5. Make a list of at least twenty-five solids and ten liquids in your environment.
6. How do elephants, cattle, sheep, vultures, weeds, and birds affect their environment.
7. Make a list of ten ways in which man makes his environment work for him.
8. List five things which each of your five senses has taught you.
9. How do you know that water is heavy? How do you know that looking at the moon over your left shoulder will not bring you bad luck? How do your answers to these two questions differ?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Barrus. John Burroughs — Boy and Man. Doubleday, Page and Co.

Comstock. Handbook of Nature Study. Comstock Publishing Co.

Patch. A Little Gateway to Science. Atlantic Monthly Press.

Sears. The Earth and Its Life. World Book Co.

Schmucker. Study of Nature. J. B. Lippincott Co.

Williams. The Wonders of Science in Modern Life. Vol. 1. Funk and Wagnalls Co.

KEY PICTURE 2. — EXPERIMENTS OLD AND NEW.

In the upper picture Francis Bacon is examining a fowl which he buried in the snow to discover if this treatment would preserve it. This was the beginning of real experimentation. We are told that Bacon caught cold while performing this experiment and died of pneumonia, a martyr to the cause of science.

In the lower picture these pupils are using the same method of finding out scientific truth — by experiment. What Bacon could do with crude methods, you can do with apparatus provided by your school or made by yourself.

CHAPTER II

HOW SHALL YOU STUDY YOUR ENVIRONMENT?

And this our life, exempt from public haunt,
Finds tongues in trees, books in the running brooks,
Sermons in stones and good in everything.
— William Shakespeare.

Science is, I believe, nothing but trained and organized common sense.
— Thomas Huxley.

What Do You Really Know about Your Environment?

Do you ever think much about the things you see around you? Do you wonder about the air, the rain, the dew, the clouds, and the sun? To understand fully and to enjoy the interesting facts about light, about electricity, about birds and plants, you must not only see them with your eyes but at the same time see them with your mind.

You see the fog. What makes it rise? Why does it disappear? You see the rain. Where did it come from? How was it formed? You see a leaf. Why is it green? Why is it thin? Why is it flat? You see the dew. How is it formed? Could you find this out for yourself? How much do you really know about your environment?

1. Materials and Methods of Study

15. Materials for Your Study. — A great naturalist, John Burroughs (Fig. 13), sent this message to all young people:

"My Dear Young Friends:

The most precious things of life are near at hand, without money and without price. Each of you has the whole wealth of the universe at your very doors. All that I ever had and still have may be yours by stretching forth your hand and taking it.

John Burroughs."

Mr. Burroughs was referring to your environment as the source of all your pleasures in life. Sky, air, water, soil, light, flowers, birds, animals, and human beings surround you everywhere.

It is surprising how little most people know concerning the most common things about them. This is because they have never been trained to see these things and to think about them. They thus miss some of the greatest joys of life.

HOME AND FIELD PROBLEMS

Did you know that the most interesting things in your environment are right near you? They are so near you in your home, in your school, and in your neighborhood that you probably overlook them entirely. But if you should form the habit of seeing more things about you, your interest in them would increase. To observe carefully is the mark of the true scientist. And so you will find, near the beginning of each chapter, problems to be solved in or near your own home, on your way to and from school, and in your neighborhood. Use your five senses as best you can in solving these problems and write a full account of your conclusions in your Science Discovery Book. If you do this in a thorough manner, you will be surprised at your increased power to see and to understand the most common and most interesting things about you.

Home Problem. — (1) Stand in the middle of your kitchen and carefully and slowly observe everything in it. Leave the room and write out a list of all the things you remember seeing in it. Now return to the kitchen and find out the number of things you did not see at all and also the number of things you saw but did not remember. Compare your three lists. Which has the greatest number of items in it? What conclusions can you draw from your problem?

(2) Next try the same exercise in your living or dining room.

Again compare your three lists. Have you gained in your power of observing things? Explain the reason for this, if you can.

Field Problem. — Observe and then write out a full description of a park or street scene near your home, giving all the details in as good English as you can. Read your essay to your class.

16. Method of Study. — In these days things worth doing should be done according to method. You should, therefore, study your environment in a definite way so that what you learn will be of increasing value to you every day. You will learn some of the greatest secrets of Nature through experiments. Because of their importance we shall take some time and space to discuss experiments.

FIGURE 13. — JOHN BURROUGHS, the great naturalist who studied his environment seven days a week, and had eyes that could see its real meaning and beauty. This picture was taken by the author on the steps of Woodchuck Lodge, Burroughs' old home in the Catskill Mountains.

17. What Is an Experiment? — If you really wanted to find out at just what temperature water boils or freezes, what would you do? Why, you would boil water and test it with a thermometer or set a pail of water outdoors on a cold winter day and note the reading of the thermometer when ice begins to form in the pail. By this simple method probably more valuable discoveries have been made in the past 100 years than during the whole period of recorded

history before 1825. Because experiments have taught us so much, we should know just what an experiment is.

An experiment is an attempt to make Nature answer a question.

18. Why Are Experiments Valuable? — Through experiments Thomas Edison was able to produce the phonograph, the electric light, and the electric car. Through experiments your enjoyment of the radio is made possible. Experiments save us much time and energy when we use their practical results and they help us to think correctly. In working experiments we use what is called the *scientific method*. By using this method we become *scientists*. (Key Picture 2.)

19. Science and Superstition. — For hundreds of years people were superstitious. They believed in evil spirits; that good luck would follow the finding of a horse shoe, and bad luck would follow the breaking of a mirror. Even to-day some office buildings have no floor numbered "13" nor any room "13."

On the other hand, science teaches us that everything in this world happens according to law. Every cause has its effect. A boy takes a bite from an apple being eaten by a playmate who has tuberculosis (tōō-bẽr-cū-lō′sĭs). He, too, gets tuberculosis. What is the cause? the effect?

Why were so-called witches not scientists? Are fortune tellers scientists? Explain your answer. Make a list of at least a dozen superstitions which your parents or other persons can relate to you.

20. Steps in the Working of an Experiment. — Let us now actually ask Nature a question and see if we can get her to answer this question. Here it is: *Which is heavier, a quart of water or a quart of milk?* Now we can all guess which is heavier and some of us are bound to be right, but we shall not know that we are right. We can, of course, take some one's word for it, but that is sometimes uncertain. The thing to do is to *prove* which is heavier by an experiment. So important is this experiment that we shall call it a

Key Experiment, the first of many that we shall perform in order to become thoroughly acquainted with our environment.

DEMONSTRATIONS

An attempt to answer any question for the first time by the use of materials in accordance with the six steps outlined below is called an *experiment.* If you perform this experiment the second time before the class, you are demonstrating to them a process or fact which you have already discovered. You are now performing a *demonstration* or "showing." Likewise, if the teacher performs this first key experiment, for example, before your class, it is a demonstration. Why? About one-half of the exercises in this book are experiments to be performed by you; the remainder are demonstrations to be performed by your teacher alone or with your help.

(Key) Experiment or Demonstration 1: — ***Problem: Which is heavier, a quart of milk or a quart of water?*** This is the statement of the problem and we shall call this *Step 1.*

Step 2: Here we collect the *Materials* or *Apparatus* (ăp'ă-rāt'ŭs) needed to perform our experiment (Fig. 14a). In this case the materials will consist of a platform balance, two one-quart milk bottles, a quantity of water, and enough milk to fill one of the bottles just even with its top.

FIGURE 14A. — (KEY) DEMONSTRATION 1. ONE WAY OF LEARNING.

Name the materials to be used here. Tell how they are to be used.

Step 3: It is here that the real experiment begins. We do the things necessary to produce a result. This step is called the *Method.* In every case this step must be *very carefully done.* In this experiment the bottle is filled with water to its very top and then weighed. This weight is noted. Then the water is poured out and the bottle dried. The

milk is then poured in to the very top and again the bottle is weighed. This weight is also noted.

Step 4: Here we record very carefully what happened or what we saw as a result of our method. This we call *Observations.*

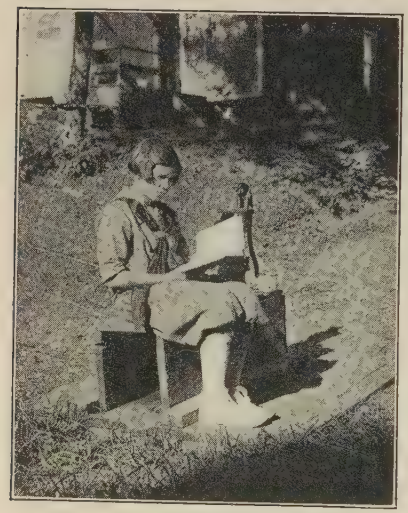


FIGURE 14B. — ANOTHER WAY OF LEARNING.

By what method is this girl learning? She is reading a book on Nature. Which is the best way to learn of your environment, — to read a book about it or to study it with your own eyes? Explain.

Step 5: The *Conclusion* is now to be drawn based upon the observations after the problem has again been carefully read. What was the problem? The record you made from the reading of the scales will give you the conclusion. What is it?

Step 6: Whenever possible, your conclusion should be used to help you learn some great fact or law or to help you to solve problems which might arise later. Suppose that your milk looks thin and bluish and you suspect that it is being "watered." You now know how to find out if this is true. Explain. Weighing equal amounts of each, you will find that they weigh almost the same. If you test the milk on several days and always get the same results, you may conclude that your milk does not weigh as much as it should. It has been "watered." This would be the *Practical Application* of your experiment.

In the above experiment you have used the scientific method. This is simply the solving of a problem by (*a*) the collection of materials, (*b*) the use of materials in such a way as to produce a natural result, and (*c*) the drawing of a conclusion from this result.

21. The Form of an Experiment. — The six steps of (Key) Demonstration 1 give you an idea of the form every experiment should take when being written down in your Science

Discovery Book. This is almost as important as the experiment itself. Nothing will help you to become a scientist so much as working out all your experiments in a definite way and recording them in a careful and methodical manner. Experience has proved that the form below will give you the best results if you will follow it.

(1) Problem: (What is to be found out).

(2) Materials: (What is to be used to answer the question or solve the problem).

(3) Method: (How the materials are used to solve the problem).

(4) Observations: (What occurs or what happens as a natural result).

(5) Conclusion: (The answer to the question or problem).

(6) Practical Application: (How the conclusion can be used to help you solve other problems or to increase your knowledge of everyday life).

FIGURE 14c. — STILL ANOTHER WAY OF LEARNING.

This boy is studying birds through a bird glass. What method of study is he following? Compare with Figure 14b and tell which is the better method. Give your reasons.

Wherever possible simple sketches should be made to accompany your experiment or demonstration and these sketches should always be labeled. Drawings without labels are worthless. To make a good-looking page in your Science Discovery Book it is well to place these drawings in a square space $2\frac{1}{2}''$ to $3''$ in width at the right side of the page opposite the word "Materials." Practice in the use of this form will improve the appearance of your book.

2. How True Scientists Use the Materials and Methods of Study

22. How Scientists Use the Scientific Method. — How do real scientists proceed to ask a question of Nature? What does a real scientist do when he makes use of the scientific method?

Suppose you see just how one great problem was solved by scientists. Yellow fever once numbered its victims by the millions. It has now practically disappeared. How did this come about?

Three doctors, Lazear (lȧ-zēr′), Reed, and Carroll, of the United States army, suspected that a certain kind of mosquito spread this disease by biting people. It was the common belief that yellow fever was spread through contact with the clothes of persons having the disease. To get at the real truth of the matter an *experiment* was necessary. These doctors stated the problem to themselves something like this: *Problem*: *Is yellow fever carried by insects* (*mosquitoes*) *or by the clothing of people who have the disease?*

The three physicians next set to work to find the answer to this question. What were the materials which they used?

Materials: A well person; a screened building; clothing and bedding of a person who had died of yellow fever. Now what did they do with these materials? How did they use them to bring about a natural result?

Method: They placed the well person in the screened building where no mosquitoes could reach him, but they had him wear the garments and sleep in the bedding of the person who had died of yellow fever. What happened as a natural result of this method?

Observations: Nothing happened. The well person did not get sick. These doctors wanted to be sure, however, so they tried the same thing with other well persons but with the same result. What did they conclude?

Conclusion: Yellow fever is not carried by clothing. Something else carries the disease. Of what good was this conclusion?

Practical Application: People did not now need to fear to come in contact with people suffering from the disease of yellow fever.

23. A Practical Problem. — But another problem now faced these three scientists, which must be answered or solved by means of an experiment. Were their suspicions right? Do mosquitoes of a particular kind (Aëdes) carry the disease? This was the problem to be solved.

They first hatched some of the Aëdes mosquitoes and allowed them to bite persons who had never had yellow fever. No symptoms of the disease appeared. This seemed to prove that the Aëdes mosquito (if it is a carrier of yellow fever) will not give the disease to a well person through biting him, if it has had no contact with persons suffering with the disease.

Now read the above paragraph over very carefully and point out (1) the problem; (2) the materials; (3) the method; (4) the observations; (5) the conclusion; and (6) the practical application (if any).

Finally, some of these Aëdes mosquitoes were allowed to bite a well person *after* they had bitten a person having yellow fever. The persons thus bitten developed the disease. Dr. Lazear was one of these persons and died, — a martyr to the cause of science and humanity. This last step proved, without any doubt, that yellow fever is carried by the Aëdes mosquito from one person to another.

The great truth at once seen was this: If the Aëdes mosquito can be destroyed, yellow fever will disappear. A method of killing mosquitoes was already known and a practical test was at once made.

The Panama Canal had failed of being built because the workers in great numbers died from yellow fever. Men would not go there to work. The United States government sent

Colonel Gorgas, an army surgeon, down to Panama and he began to drain and oil the swamps. Yellow fever began to disappear. The Panama Canal was built and the Canal Zone was changed from a pesthole to one of the most healthful spots on earth (Fig. 15). Had it not been for the work and experiments of the three army physicians and their helpers,

Ewing Galloway.

FIGURE 15.—A HOTEL IN THE PANAMA CANAL ZONE.

Name several factors which make this hotel environment ideal. Twenty years ago such a hotel in the same place would have been impossible. Why?

the United States could not possibly have brought the construction of the Canal to so early a close. This work was done by the *scientific method*. What do you think is meant by the scientific method?

Now read over very carefully the last three paragraphs and point out the *problem*, the *materials*, the *method*, the *observations*, the *conclusion*, and the *practical application*. Write out these statements in your Science Discovery Book.

Woolworth Building Co.

FIGURE 16. — MAN'S CONTROL OF HIS ENVIRONMENT.

These great buildings are the result of many years of experimentation. To know how to put such buildings up, how to build their enormous foundations, how to make the steel frames and fit them together, and how to cut the stones and raise them into place is the result of experiments. All such experiments are conducted by the scientific method. To guess at constructing these buildings would make them unsafe and useless. Explain.

3. How You May Become a Scientist

24. How Should a Young Scientist Work? — You may now well ask yourself this question: How can I, too, be a real scientist? By carefully following the method outlined in Section 21 and applying it to every thing you desire to find out concerning the factors of your environment, you will be on the high road to becoming a young scientist.

You will be using the very same method which Lazear, Reed, and Carroll used. By this same method Pasteur (pȧs'tûr'), Koch (kŏk), Lister, Marconi, Morse, Bell, Edison, De Forest, Burbank, and thousands of other scientists have made their discoveries.

25. Some Experiments for You to Work. — Having learned how an experiment is worked, you can now test your ability with some real problems of your everyday life. Put these in the form of questions which you can ask of Nature and make her give you the correct answers. Here are the questions:

1. What makes the water stay in a glass tube when you hold it up with your finger over the top end of the tube?

Suppose that we give you a little start on this first one. Your problem has been stated. What is step 2? What materials do you use? What method do you follow? Be sure that you completely fill the tube with water before taking it from the jar containing the water and also be sure that you do not remove your finger from the tube. (You can get the water up into the tube by drawing it up with the mouth and then putting the finger over it while the end of the tube is in the mouth.) Now remove the finger from the end of the tube. What happens? Fill the tube again. Remove the finger again. What is the method? What observations do you make? As you work, THINK! What conclusion can you draw? How could you use such a tube (rubber or glass) in a practical way?

Now come the rest of the questions. Work them out by yourself, following carefully the six steps.

2. Why does oil rise in a lampwick?
3. What effect does an acid have upon baking soda?
4. What effect does light have upon a green plant set in the window?
5. Through what part of a stem does sap rise?

KEY WORDS

Look back through this chapter for the following key words, and make sure that you can explain each one.

apparatus	Lazear*	Reed*
Carroll*	materials*	scientific method*
conclusion*	method*	scientist*
demonstration*	observation*	superstition*
experiment*	practical application*	yellow fever*
Gorgas*	problem*	

REVIEW OUTLINE

1. What We Shall Study: Our environment.
2. How We Shall Study: By reading; by observations; by experience; by experiments.
3. What an Experiment Is: An attempt to make Nature answer a question.
4. Why Experiments Are Valuable: They aid industry; help in making new discoveries; increase our comforts; conserve living things; help make scientists.
5. Science and Superstition: Science is based upon experiments and teaches us that every effect has its cause. Superstitions are beliefs based upon few facts and no experiments.
6. Steps in the Working of an Experiment: *a.* Problem; *b.* Collecting materials; *c.* Method; *d.* Observations; *e.* Conclusion; *f.* Practical Application.
7. How Scientists Use the Scientific Method: Work of some American scientists (Lazear, Reed, Carroll). Conclusions based upon experiments and not upon guesses and beliefs.
8. How a Young Scientist Should Work: *a.* By following the scientific method; *b.* By studying the methods of great scientists.

SUMMARY

You can learn by studying your *environment.* The best method is by *experiment* because you ask questions of Nature and try to make her answer them. What you learn by experiment you seldom forget.

All the factors of your environment *work* according to *law.* Experiments enable you to discover these laws. When you know the laws of nature, there is no room for *superstition.* Because of this, you should learn how to conduct an experiment according to the *six definite steps.*

With the knowledge of how to perform an experiment you will be more interested in knowing how great *scientists* have used these same steps in making great *discoveries* or great *inventions*.

Knowing how scientists use these six steps in arriving at a conclusion, you can learn how to follow them and become a scientist yourself.

Remember that:

1. The study of science is the study of your environment.
2. The best way to study science is by the use of experiments.
3. Experiments, if properly worked, will give you the exact truth.
4. The present advancement in industry, in transportation, in sanitary living, and in control of disease is due entirely to experiments in science.
5. All scientists gain correct knowledge step by step through the use of the scientific method.

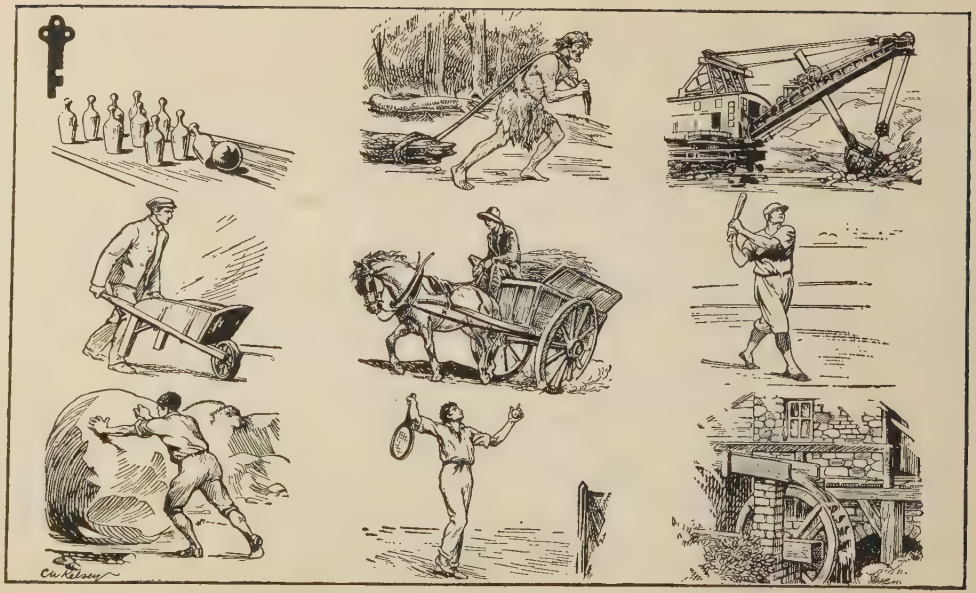
THOUGHT QUESTIONS

1. In what ways are the environments of all living things alike; in what ways are they different?
2. In what regions of the world is most work done? Where is the least amount of work done? Account for this.
3. Mention ten different kinds of work that men do. What do they all really do in this work? Explain.
4. Name ten facts you have learned from text-books which you have never proved for yourself to be correct. Why do you accept these facts as true?
5. Name five things you have learned from experience and tell just how you learned these five things.
6. Give two things you have learned by experiment. Was what you learned by this method right or wrong? Explain.
7. What countries to-day are rich in superstitions? What countries are rich in science? Are any of the countries you name rich in both science and superstition? Explain.

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Bolton. Famous Men of Science. Crowell Co.
Brooks. Benjamin Franklin. Lothrop, Lee and Shepard Co.
Burroughs, John. Works. Houghton, Mifflin Co.
Darrow. Masters of Science and Invention. Harcourt, Brace and Co.

Libby. History of Science. Harper Brothers.
Meadowcroft. Boy's Life of Edison. Harper Brothers.
Mills. The Adventures of a Nature Guide. Doubleday, Page and Co.
Mosely. Trees, Stars and Birds. World Book Co.
Stone and Fickett. Famous Days in a Century of Invention. D. C. Heath and Co.
Weed. Seeing Nature First. J. B. Lippincott Co.
Williams. The Wonders of Science in Modern Life. Funk and Wagnalls Co.



KEY PICTURE 3. — FORMS OF MATTER AND ENERGY.

Study carefully each picture above and tell in each case the forms of matter illustrated and the form of energy that is doing work by acting upon or through the matter. If you understand this picture the chapter following will be clear to you.

CHAPTER III

THE WORK OF MAN IN HIS ENVIRONMENT

The heights by great men reached and kept
Were not attained by sudden flight,
But they, while their companions slept,
Were toiling upward in the night.

— *Longfellow.*

Let us first understand the facts and then we may seek the cause.
— *Aristotle.*

Have You Ever Been in a Workshop?

What is a workshop for? Are there any workshops in your town or city? Name at least five things that you will find in any workshop you may have in mind. What runs the workshop? What is produced there? Has your father a workshop at home? If so, name several tools he uses there. Workshops are usually in barns, in special buildings set aside for them, or in garages, are they not? Did you ever think that it would be possible to have a workshop right out of doors? If a man were building a cellar wall for a home, would not that be his workshop as long as he worked at that spot? Think of several workshops of this kind you have seen in your town.

Home Problem. — Make a list of all the things used in your home by the members of the family which help lighten their work. Determine the work most often done in the home.

Field Problem.—On the way to school some morning make a list of all the kinds of work you see being done and indicate what devices are used to help do this work.

1. What Is Man's Workshop?

26. Man in His Workshop. — The environment of man is his workshop. He may work out of doors as a farmer or woodsman or in his shop as a mechanic (mĕ-kăn'ĭk). He may work in his home building a radio outfit, or he may be busy on a moving train, or in a steamship. Each is working in his natural workshop and using the factors of his environment in this workshop.

The factors of his environment are the tools and the raw materials for building his home, making his clothes, and feeding his body. They not only supply these necessities but also make possible the luxuries and comforts which make life interesting and enjoyable. These factors, air, soil, tools, water, heat, electricity, cooking utensils, foods, cloth, woods, and the like, all occupy his time and his energy. The world is man's workshop.

27. Man and Matter. — Almost all the things named in the above paragraph can be seen and handled. Man comes in contact with them every day. Every object or substance which you handle or use in your daily lives is known as *matter*. **Matter is anything that occupies space.** A hammer, a book, salt, air, water, iron, gasoline, a chair, a street car are all examples of matter. A little study of matter as you find it will show you that it takes many forms and shapes and is composed of many different things. A little observation will also show you some important and interesting facts about its form and composition.

Carefully study Key Picture 3 and make a list of all the different materials (matter) there shown. How many items do you find in your list? How do these various materials differ from each other? How many are alive? How many are not alive? Is work being done in this picture? Explain.

On your way to and from school note as many different examples of matter as you can. Classify them after reading section 28. Which ones are being used by man in his work?

SUGGESTED EXPERIMENTS

Throughout this text-book you will often find the words "Suggested Experiment" right in the middle of a paragraph. Whenever these words appear you will know that here is a question you can put to Nature with a very good chance of securing the answer. These experiments can be done either at home or at school. It is hoped that you will try to do many of them. In doing them you will try to use the scientific method and thus you will become day by day a better scientist. But always remember this: Think while you work! All good scientists *think*. Again, be sure that you draw a correct conclusion. Finally, try your best to see some *practical use* of your conclusion. This is the real value of science in everyday life.

Suggested Experiment. — Suppose that you arrange in a row upon a table a piece of iron, some sand, a piece of wood, a small stone, a small strip of copper, a piece of glass, a piece of charcoal, a piece of paper, a teaspoonful of granulated sugar, a small piece of bread, a bit of humus soil, and a small piece of cooked meat. Light a Bunsen burner and by the aid of pliers and an iron spoon hold each substance in the flame for some moments. Note the results in each case. Now if this demonstration were placed in the form of a question put to Nature, how would it be stated? What would be the method? What would be the results? What would be your conclusion? Write this experiment out in full in your Science Discovery Book in proper form as suggested on page 35.

28. Two Main Classes of Matter. — Substances which turn black when highly heated are *organic* matter. They are either alive or once formed a part of a living thing (organism). (Chemists have discovered that certain organic substances may be artificially produced, and so in chemistry the term *organic* does not always imply life activity.) The hand, a leaf, sugar, bread, charcoal are all organic matter. Iron, granite, air, and pure water are *inorganic*. Why?

29. Matter Differs in Its Form. — Again, matter takes on different forms or states. In many cases the same bit of matter may take several different forms. You can prove this for yourself in the following manner:

Suggested Experiment. — Secure a piece of ice about three inches in diameter. With a hammer break this ice into smaller pieces. Note that it takes some force to do it. This is because ice is a *solid.* Now place a small piece of the ice in a glass beaker and set the beaker over a Bunsen or an alcohol flame. What happens to it? Note that it changes its form. It is now a *liquid.* Keep heating this liquid until it boils. Steam is given off and passes off into the air as a *gas.* The ice has finally disappeared into the air, but we know that it is still in existence in another form.

FIGURE 17. — KINDS OF MATTER.

Name all the environmental factors here. Which are alive? Which were once alive? never alive? Which are organic? inorganic? Which are natural? artificial?

If this problem you have just solved was placed in the form of a question, what would this question be? What would be a list of the apparatus used? What would be the method? What would be the observations? What would be the conclusion? Write this experiment out in proper form in your Science Discovery Book, making labeled drawings to show the materials used. After this is done answer the following questions:

1. What are some of the things you have learned about a solid, a liquid, and a gas?
2. What is a solid? a liquid? a gas? Use the dictionary, if necessary, to help you.

3. Give several original examples of organic matter; of inorganic matter; of solids; of liquids; of gases.

4. Why is each of the examples you have named in question 3 called matter?

Write out these answers for future reference in your Science Discovery Book.

Matter, then, is everywhere. We use it every day. Science could not exist without matter, since matter is the source of most of our knowledge and knowledge properly used is science. (Key Picture 3.)

30. Other Important Facts about Matter. — Certain qualities are found in all matter. These qualities are known as the *general properties*[1] *of matter.* For example: A block of steel (a solid) occupies space and has weight. Are these two properties of steel true of all matter? In answering this question you will have your first opportunity to put a demonstration in proper form.

Demonstration 2: *Problem: What are two of the general properties of matter?*

Materials: A glass graduate; a beaker of water; a string; a stone small enough to pass freely into the graduate; small weights; two books; a smooth wooden ball; and a table.

Method: A. Set the ball on the table. Give it a slight push. Note what happens to it.

> For the sake of simplicity and clearness you will often find it best to divide the method into *A*, *B*, and *C* parts, especially when it is desired to show more than one thing in order to prove the problem or answer the question. Likewise, the observations should be lettered (*a*), (*b*), and (*c*) to correspond with the parts of the method. This will avoid confusion. Try this when you think it wise and see if it does not help you.

B. Tie the string around the stone and lower it into the graduate of water. Now try to put two books in the same spot at the same time on a table. Note the result here and try to account for it.

[1] A property of matter is anything you can learn about it (color, weight, texture, etc.) by use of your five senses

Observations: Write out carefully what happened in *A* and *B* above. Why did the ball remain still when placed on the table? Why did it roll along the table? Why did it stop rolling? Do things (matter) tend to remain as they are? Would a thing (ball) when made to roll keep rolling if not stopped by some thing outside of itself? This action or inaction of matter is called *inertia* (see p. 55). Why did the water rise in the graduate? Is water matter? What is one general property of all matter? Could the stone and water or the two books occupy the same space at the same time? Why? This is called the *impenetrability* of matter.

Conclusion: What are two general properties of matter?

But some kinds of matter have special qualities or properties not possessed by others.

Suggested Experiment. — Suppose that you secure a rubber ball, a piece of clock spring or a scroll (skrōl) saw blade, a piece of wire solder (sŏd′ĕr), a piece of sheet tin 6 inches square, a piece of glass about 4 inches square, an iron rod, and two pairs of pliers.

Now hold one end of the saw blade or spring in one hand and with the other bend the blade or spring out some distance and suddenly let go. Now do the same with the wire solder. Do they act alike? Which is elastic? Try to squeeze flat the rubber ball. What prevents this? Why does the ball take its round shape when pressure is released? Is *elasticity*[1] (ē′lăs-tĭs′ĭ-tĭ) a general or a special property of matter? Explain. Next hold the tin and the glass between your eyes and the light, one after the other. Does the light go through each? What name is applied to matter which will not let the light through it? Why is glass called *transparent?*[2] When is it called *translucent* (trăns-lū′sĕnt)?[3] Finally, hold one end of the wire solder with the pliers and have another pupil pull on the other end of the wire with a second pair of pliers. What happens? Try the same with the iron rod. Which of the two pieces of matter tested is *ductile?*[4] Did you ever pound a copper rivet flat with a hammer? Copper is *malleable.*[5] Have you ever noticed that a

[1] Elasticity is the tendency of a substance to take or regain its original form when force has been removed from it.

[2] Transparent: a term applied to matter through which one can see.

[3] Translucent: a term applied to matter that light will go through, but which cannot be seen through.

[4] Ductile: a term applied to matter which can be drawn out, as into wire.

[5] Malleable: a term applied to substances which can be beaten into a desired shape.

piece of wood soaked in water is heavier than a dry piece of the same size? The wood absorbed the water because it was highly *porous*.[1]

Can you easily cut steel? Why? Can you easily break a clay pipe stem? Why? Write a story of the answers to the above questions in your Science Discovery Book.

31. Why Properties of Matter Are Important to Man. — It is very plain that if all matter did not occupy space, did not have weight, and was not impenetrable (that is, if two bodies of matter could occupy the same space at the same time), we could see and feel nothing because there would be nothing to see or feel. Nothing would exist, not even ourselves. If all matter were elastic, our buildings would not be stable and if all matter were inelastic life would be hard indeed.

Make up a list of five elastic, five inelastic, five transparent, five ductile, five malleable, five hard, and five brittle substances. Tell how and why each is useful or useless where you find it. Add to this list as your observations are carried on.

2. Some Aids and Handicaps to Man's Work

32. Man and Energy. — Matter is *inactive*. It cannot move itself. It must be moved by some push or pull which we may call a *force*. Force produces motion. Back of the push or pull (force) is energy. What is energy?

Energy is the capacity or ability to move something (as when a boy moves a chair) or to overcome resistance (as when a boy tackles a runner in a game of football). Energy is the capacity to do work. And remember that energy alone can develop force to move matter. Motion is possible only where matter is present. Can you see this?

33. Forms of Energy. — In picking up a book you use muscular force. But your muscles are in turn able to move because they possess energy and release it in the form of mo-

[1] Porous: a term applied to substances which will absorb water.

tion. Energy stored in the muscles of the arm may be released in the form of heat and motion. The hand may place a cartridge in a gun (motion) and pull the trigger (motion). The impact of the hammer ignites the powder in the shell. The carbon is burned by chemical action, and the heat produced expands the gases formed, which drive the bullet from the gun. Heat, chemical action, electricity, and motion are all forms of energy.

34. Kinds of Energy. — When energy is doing something it is *active* or *kinet'ic*. When steam moves something, the heat energy in it changes to kinetic. Before the Bunsen burner is lighted the heat is not present. It is hidden in the gas. It is *stored* or *potential* energy. Electrical energy rings the door bell. It is then kinetic. When the bell is not ringing, where is the energy? Explain. (Key Picture 3.)

When will the stored energy in coal be of use? Why is coal bought? When you wind up a clock, you have stored energy in the spring. It soon makes the hands go round and becomes active.

Science has a good deal to do with energy. Men are constantly trying to find out new and easier methods of *using energy to move matter in order to lighten work*. Without energy no work would be possible because no matter could be moved.

1. Make a list of the factors of your environment which can move or make things move.
2. Make a list of the different forms of energy which act upon the factors of your environment.
3. Name at least ten occupations in which the moving of matter is very important.

35. Man and Work. — You have already learned that man is a working animal. What is work?

Work is the moving of matter through space (moving a chair) or the checking of the movement of matter through space (catching a ball). Work is also the overcoming of resistance (one boy pushing another against his will in a wrestling match). (Key Picture 3.)

But remember that work means more than just doing something. A girl may be holding a pound of sugar in her hand or a boy may be pushing on the end of a piano. Scientifically speaking, neither is doing work, because while effort may be used no movement results and so no work is done (see definition). Keeping in mind the meaning of work, answer the following questions:

1. Does a boy work when he plays ball? Does a girl work when she plays tennis?
2. Does a boy do work when he tries to pull a stick out of the ground or to lift a stone and fails? Explain. (See Key Picture 3.)
3. List six different things a boy can do which mean work.
4. List six different things a girl can do which mean work.
5. List the factors of your environment which might do work.

Take great care in the preparation of the above statements and record them in your Science Discovery Book for future use.

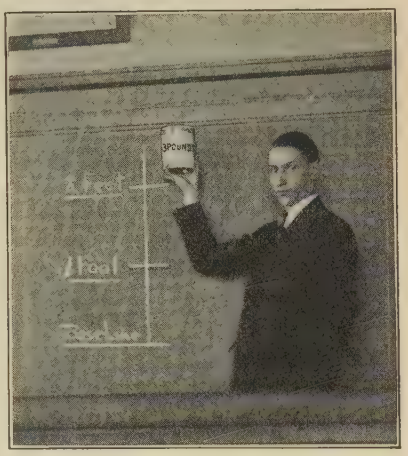


FIGURE 18. — HOW WORK IS MEASURED.

This boy has raised the three-pound jar two feet up from the base line. He has done six foot-pounds of work. Explain. Had he raised it to the one-foot mark how much work would he have done? Explain.

36. Work Can Be Measured. — If you lift a pound of sugar up from a counter through a distance of one foot, you have used a push or a pull to overcome resistance (weight). This push or pull we call a force equal to one pound. You have done one foot-pound of work. *Work, then, is measured by multiplying the force by the distance* (Fig. 18). In other words, the amount of work done (foot-pounds) equals the pounds × the distance

(feet). Expressed by a symbol or equation it would be: $W = F \times D$.

1. How much force would be required to lift a 100-pound weight ten feet off the ground?

2. How many foot-pounds of work would be done in lifting a 100-pound weight up ten feet from the ground?

But remember this in connection with work: The amount of time used in doing any piece of work has no effect upon the amount of force required to do the work. Hurrying work does not, therefore, lessen it. Explain.

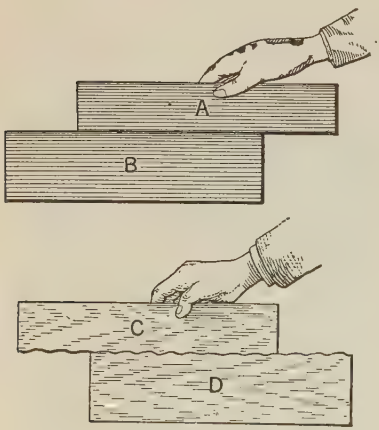


FIGURE 19. — CAUSES OF FRICTION.

When **A** is moved over **B**, very little effort is needed as compared to that required to move **C** over **D**. Explain the difference. Will friction act if the blocks are at rest? What are two conditions that will cause friction? Upon what will the amount of friction depend?

37. What Makes Work Hard? Suppose you find this out for yourself. (Key Picture 3.)

Suggested Experiment. — With the help of one of your companions get together a table, a wooden box about 18 inches long, and six to eight bricks or two dozen textbooks. Put the box on the table and put into it all the bricks or books. Now lift the box. Is it easy? Explain. Try pushing the box along the table. Is it easy? Explain. Try moving the box a second time, noting carefully when the effort to move it is greatest and when least. Do you notice a difference in the amount of force needed at any time? Was work done here?

38. Weight, Friction (frĭk′shŭn), **and Inertia** (ĭn-ûr′shĭ-*ă*) **in Their Relation to Work.** — Weight is our way of measuring the force of *gravity* pulling an object down. We thus

measure the force of gravity in tons, pounds, and ounces. Gravity made the box of books heavy. All objects in the universe attract one another, and this attractive force is called *gravitation*. An example of it is the sun's attraction for the planets. The form of gravitation which we call ***gravity is the earth's attraction for objects on or near it.***

The rough under surface of the box rubbed hard against the surface of the table, causing *resistance* to your muscles. This form of resistance is called *friction*. What is friction?

Friction is the resistance to an effort to cause one body or surface to slide or roll over another.

The rougher the surfaces rubbed together, the greater the friction and resistance (Fig. 19). A boy sliding slowly down a rope can easily stop by tightly grasping the rope. Friction does it. The Indians dragged their loads about on poles hitched to their horses. This was hard work. Why? If you will place two or three round lead pencils under the box of books or bricks, the box will move very easily. Explain. To reduce resistance from friction still further, man invented the wheel and rolls his loads over the roads. By improving roads, using grease, oils, and roller bearings, he has made his work even lighter. Explain.

Friction, however, is useful to us as well as a hindrance. Ashes and sawdust placed upon icy sidewalks prevent slipping. Sand placed on the rails allows a locomotive to climb a grade. Explain. Without friction no one could stop an automobile even with brakes nor could it be started. We could not walk without friction. We lift objects in our hands partly by friction. Where does friction work in Key Picture 3?

The third form of resistance to effort is not so easy to explain. It was hard to start the box of books moving, but once in motion it moved more easily. What is *inertia?*

Inertia is the tendency of a body at rest to remain at rest (a ton of coal) and of a body in motion to remain in motion (a ball when thrown).

Inertia makes it hard to push a "dead" automobile out of the road. Inertia throws standing passengers in a street car off balance when the car suddenly starts, stops, or goes around a curve (Fig. 20). On the other hand, airplanes and steamships could not travel were it not for the inertia of the air and of the water. Explain. Study inertia in Key Picture 3.

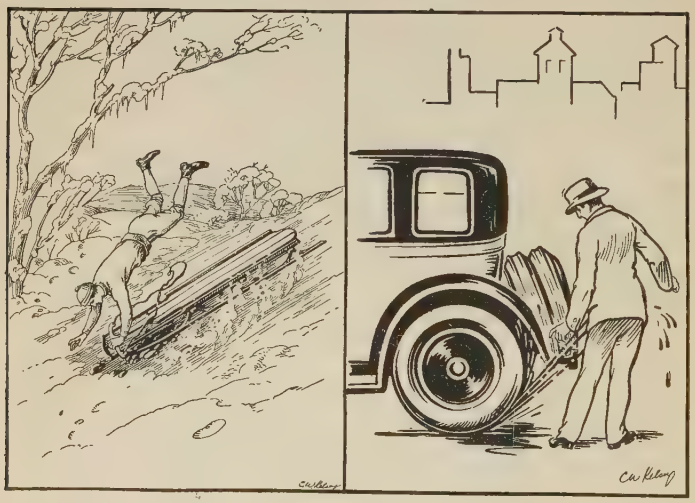


FIGURE 20. — THREE FORCES AT WORK.

What caused the sled to go down the hill? What caused it suddenly to stop? Why did the boy go on? Explain fully.

What threw the mud up from the ground? Why did the mud fly straight out from the wheel? Where did most of it finally come to rest? Why?

3. How Man Uses Machines to Lighten His Work

39. Some Common Aids to Work. — In the course of time, man learned to use simple machines to lighten his work. The *lever* (lē′vẽr), the *inclined plane*, and the *wedge* (Figs. 22a, 22b, and 22c) are probably the first three devices used by man, and, strange to say, the same machines, with but little improvement, are in use to-day. His club or axehandle was his lever, the blade of his axe or rude knife was his wedge, and a graded mound of earth was his inclined plane used to help

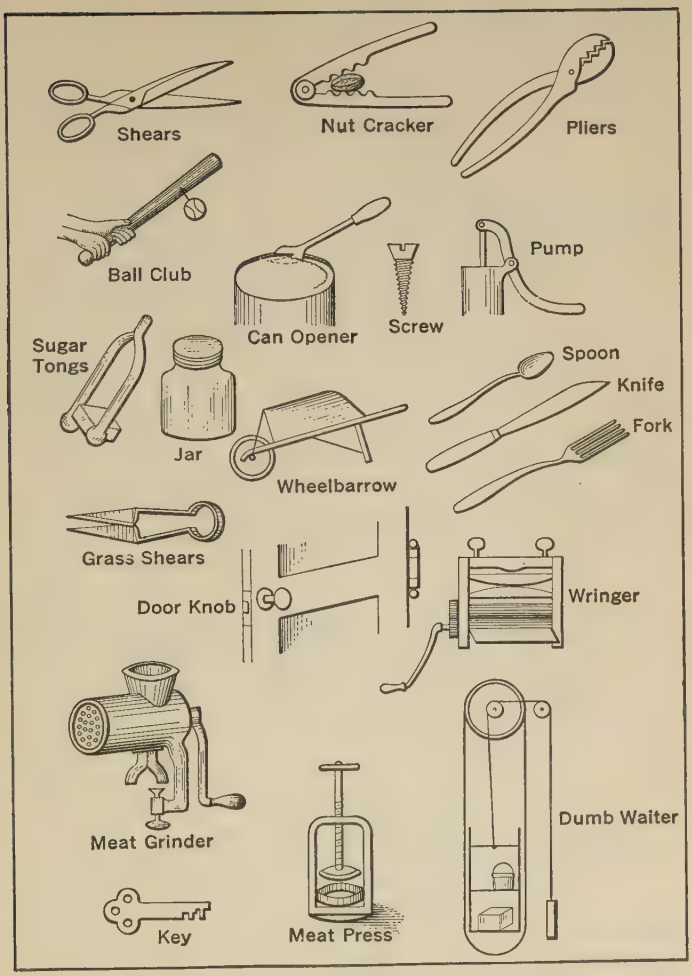


FIGURE 21. — SOME COMMON UTENSILS WHICH ARE MACHINES.

Show how each is a machine. Point out the effort arm (see section 41), the resistance arm, and the fulcrum in each utensil.

get stones into place in building a wall. To-day we use the same things in our work in and about our homes.

Knives, forks, spoons, crowbars, shears, plows, hoes, keys, door knobs, jack-knives, and a thousand and one other simple tools are *all simple machines.*

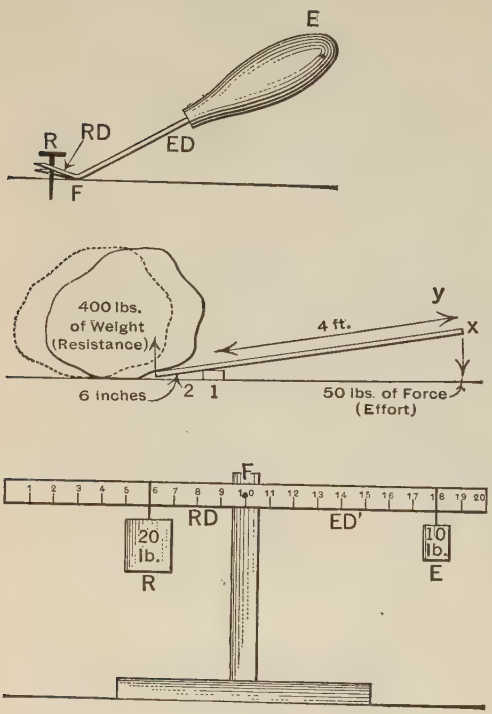


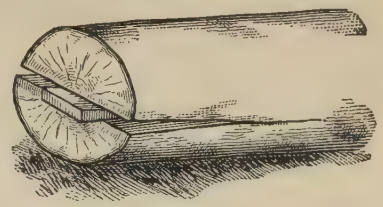
FIGURE 22A. — THREE FORMS OF THE SAME MACHINE, THE LEVER.

In what ways are they alike? How do they differ? Where is the force applied in each picture? Where is the resistance? Where is the fulcrum? In the second picture what do 2 and 1 indicate? What is the 4-foot distance? Apply all the terms of the tack puller picture to this one. If **x** were raised to position **y** what change would you make in the position of 1? Would more effort be needed to move the stone than before? Explain. What do the dotted lines show?

40. What Is a Machine? — What one definition will explain all the tools already named?

A machine is a device used to change the direction of a force (as when you pull up a weight with a pulley) or to change the amount of force necessary to do some useful work (as when you move a heavy stone with a bar). A machine may also transfer energy from one place to another (as when you transfer energy from a bicycle pedal, through the chain to the rear wheel).

The tackpuller (Fig. 22a) enables one to do easily what it would be impossible to do with the hand alone. Explain. This simple tool is called a *lever*. Why is it called a machine? It took ages for man to develop this machine. Now you can buy one at the hardware store for ten cents.



Other *simple* machines are the *screw* (a bolt or corkscrew), the *pulley* (used to balance a window-sash and weight), and the *wheel and axle* (a bicycle wheel or a clothes wringer, handle, and gears).

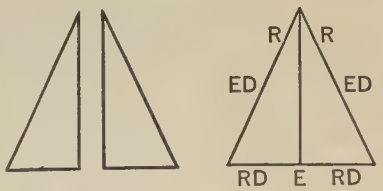


FIGURE 22B. — THE WEDGE.

What causes the cleft in the log to become larger as the wedge is driven into it?

A *compound* machine is one composed of two or more simple machines, generally of different kinds. Such a machine is a meat grinder, a typewriter, or a lawn mower. Find several compound machines in your home. In Figure 21 find examples of all the simple machines named in sections 39 and 40. Find several simple and one compound machine in Key Picture 3. None of these machines actually do work because they possess energy or can exert force. They so distribute the forces required to do the piece of work at hand that the muscles of man are partly relieved and the machine takes over the burden of the work. Man must still guide and control these machines or they are worthless.

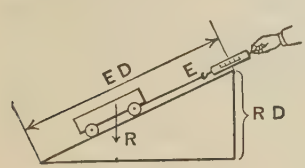


FIGURE 22C. — THE INCLINED PLANE

How much effort would be required to pull the cart along a table? to lift it up off the table? How does the inclined plane help to raise it a given height from the table?

41. The Law of Machines. — In referring to the work of a lever, we call the pivot or support the *fulcrum*. The force used to raise an object is called the *effort*. The distance between the effort and the fulcrum is called the *effort arm* or *distance*. The weight of the object is called the *resistance*. The distance between the object and the fulcrum is called the *resistance arm*. If you multiply the effort by the effort distance, it will always exactly equal the resistance multiplied by the resistance distance ($E \times ED = R \times RD$). Study carefully Figures 22a and 22b and explain how the law of machines applies to each part shown in these figures.

4. How Man Puts the Forces of Nature to Work

42. The Work of Your Environment. — Since work is the moving of something, a waterfall is doing work in moving a water wheel. The sun shining upon the water causes it to evaporate in spite of the force of gravity. The sun does work. How?

Possibly the greatest thing that man has done is to discover that the forces of Nature are at work and that he can use them to help him do his work. For example, a man could never carry a locomotive from the United States to England unaided, but the steam engine which he invented can use steam to turn the propeller of the steamship which carries the locomotive across the ocean. It is hard to pull water from a well with a rope, but an electric pump will do it easily.

43. Can a Falling Body Do Work? — Objects, since they have weight, often fall. Bricks sometimes fall and injure people. A rock falls from an embankment and wrecks a passing train. Read this newspaper account:

> A train carrying 186 German-Americans bound on a trip to Germany was wrecked this morning by sand and gravel being washed on to the track by the cloudburst which occurred at 3 : 30 A.M.
>
> — *New York Times*, June 16, 1925

Show how the hammer in Figure 23 can do work. What force and what form and kind of energy are working here? Test this out yourself.

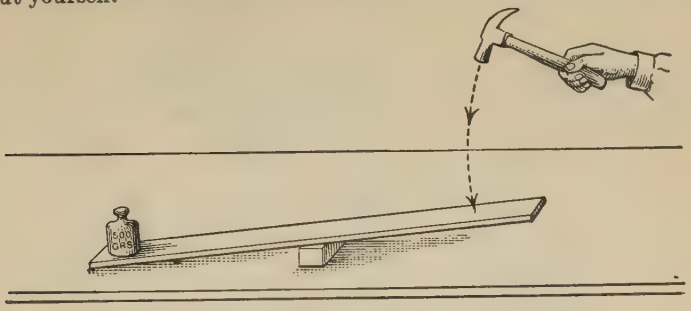


FIGURE 23. — THE HAMMER, A LENGTHENED ARM.
What kind of machine is it, as here shown? Explain.

44. Can Moving Water Do Work? — The hammer is a solid body. Is it possible that a liquid also can do work?

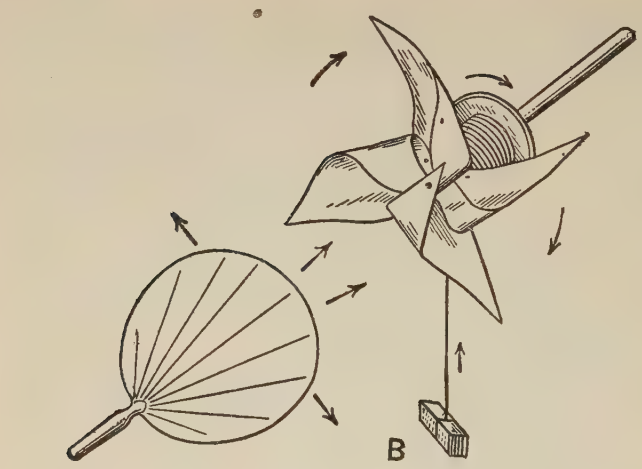
Study Figure 24, A, and tell how this experiment would show that water can do work. Test this out for yourself.

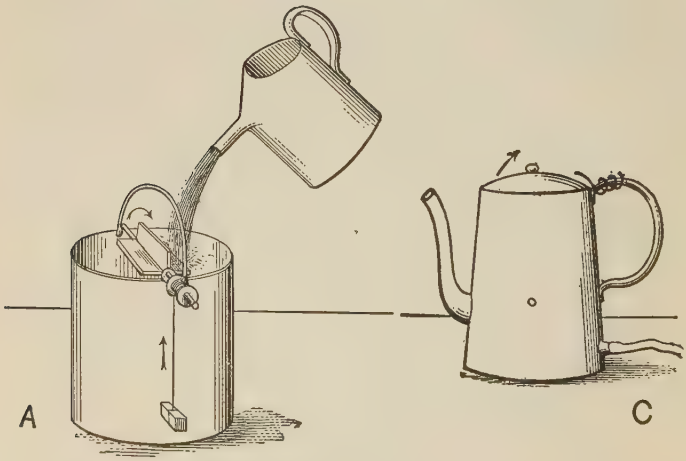
The great dam at Conemaugh, Pennsylvania, held back millions of gallons of water possessing stored energy. When the dam burst, this stored energy became active or kinetic and hundreds of people were drowned and millions of dollars worth of property was destroyed in a few minutes. This is remembered as the great Johnstown flood.

45. Can a Tornado Do Work? — You know that you cannot see air even when it is moving. Yet you can see the fearful results of its work when it moves with terrific speed. Read the following newspaper item:

TORNADO KILLS THOUSANDS IN THE WEST

March 18. A tornado tore through Southern Illinois to-day after lashing Western Missouri, and died out in Indiana after collecting a toll of 3631 dead or injured on the basis of estimates collected to-night from the storm-swept regions. Millions of dollars worth of property was totally destroyed.
— *New York Times.*





A. What causes the water to fall? the wheel to turn? the weight to rise?

B. What causes the fan to work? the windmill to turn? the weight to rise?

C. What is the use of the hole? the wire on the handle? the tubing? What does the arrow mean?

FIGURE 24. — THREE WORKING FACTORS OF OUR ENVIRONMENT.

List all the factors used in these experiments. Name all the machines shown in the three pictures. Show how friction, gravity, and inertia aid or hinder the action of each bit of apparatus here shown.

Study Figure 24, B, and explain how this experiment proves that moving air can actually do work. Make this apparatus and test it out for yourself.

46. Can Heat Make Things Move? — No one ever saw heat but we know that it exists. It is not a solid. It is not a liquid. It is not even a gas. It is not matter. It is a form of energy.

Demonstration 3: *Problem: Can heat do work?*

Materials: Secure and assemble the apparatus shown in Figure 24, C. Study this picture carefully.

Method: Allow some gas to enter the pot through the tube, leaving the cover open. Does the gas have an odor? Touch a lighted match to the top of the pot. Note result. *Caution! Allow but a small amount of gas to enter the pot at one time and hold the head away from the pot when lighting the gas.*

Now close the pot and allow some more gas to enter. Open cover for a moment and wave your hand across top of pot two or three times. Close the cover and touch lighted match to the small hole in the side or insert a red hot needle or wire through this hole. Note result.

Observations: What do you hear? What happened to the can or pot top? Was work done? What did the work? What form and kinds of energy were here shown? Carefully record all these points.

Conclusion: Write out your conclusion with reasons.

Practical Applications: What simple machine was shown in this experiment? How can heat be made to do work in your home? Why should your mother never attempt to light the oven burner of your gas stove without having the oven door wide open? Show how heat does work in Key Picture 3.

47. General Scientific Conclusions. — What correct conclusion can you now draw from your studies so far in Environmental Science? You have been observing, recording, and drawing conclusions just as Edison or any other great scientist does. Can you gather up all your ideas and draw one conclusion which you may state as a general law and which will always be true? Can you make the knowledge gained so far of very great value to you throughout the rest of your studies?

You have now learned that:

1. A boy or girl can throw a ball.	Animals can do work.	Living things can do work.	Everything which can move or cause motion can do work.
2. A horse can draw a load.			
3. A plant can grow up through the soil, pushing it aside as it grows.	Plants can do work.		
4. A hammer will move another weight.	Solids, liquids, and gases do work.	Non-living things can do work when acted upon by some form of energy.	
5. Simple tools can be used by man to lighten his work.			
6. Moving water turns a water wheel.			
7. Moving air turns a windmill.			
8. Electrical energy rings a bell.	Energy can do work.	Energy can do work when acting upon matter.	
9. Heat moves the top of a coffee pot.			

Here we have summed up the whole of our discussion on energy and work. The extreme right-hand statement is our *general law*. We shall use this law all through this book.

48. The Work of the World. — Work, then, is the doing of something which results in motion. Our modern industrial age began when the energy stored up in coal could be set free by burning it in the coal box of a steam engine (as in a locomotive). This released energy did the work of thousands of men. It is the very foundation of modern agriculture, manufacture, construction, and transportation. Think of the work done daily by the plows, the mowing and threshing machines on the 6,000,000 farms of the United States! Think of all the work done each day in the shoe, hat, clothing, tool, furniture factories, and machine shops of this country! Think of all the household duties performed by all the housewives in the United States in one day! Can you see how all the work we have talked about in this chapter was really done by the energy of the sun?

KEY WORDS

NOTE. — Do not fail to look back through this chapter for the following key words and make sure that you can explain each one of them, especially those which are starred. Record the meanings of the starred words in your Science Discovery Book.

compound machine*
effort*
effort distance*
elasticity
foot-pound*
force*
friction
fulcrum*
gas
gravity
heat*
inclined plane*
inertia*
inorganic*
kinetic*
law of machines*
lever*
liquid
machines
malleable
matter*
organic*
properties
porous
pulley*
resistance*
resistance distance*
screw*
solid
translucent
transparent
wedge*
weight arm*
wheel and axle*
work*
workshop

REVIEW OUTLINE

1. Man's environment is: his workshop; raw materials; tools.
2. Man's environment is largely composed of matter. Definition of matter. Kinds of matter (2); forms or states of matter (3). General and special properties of matter. Values to man.
3. Energy acts upon and through matter. Definition of energy; of force. Forms of energy (4); kinds of energy (2). Uses of energy to man.
4. Work is the result of a force acting upon matter. Definition of work. How work is measured ($w = f \times d$). Obstacles to work (weight, friction, inertia); definition of each. Uses of weight, friction, and inertia in everyday life.
5. Some common aids to work: simple machines (6). Definition of a machine. The law of machines: $E \times ED = R \times RD$. Explanation of terms used in describing the work of a lever. Compound machines. Definition. Uses in the home.
6. The work of: moving water (waterwheel, a form of lever); moving air (windmill, a form of lever); moving weights (pile driver, a compound machine); heat (gas engine, a compound machine).
7. General law developed from the study of matter, energy and work: Everything that can move or cause motion can do work.

SUMMARY

Read this story very carefully. A man cuts down trees with an *axe* and saws these trees into lumber at the saw mill. He is acting upon *matter*. Some of it is *organic* (the trees) and some is *inorganic* (the axe head and the saw). He uses *gas* (the air he breathes); he uses *liquid* (the water he drinks), and he uses *solids* (the axe, lumber, etc.).

In chopping down the trees, *stored energy* in the muscles of the man is released and *work* is done upon the trees. The logs are sent to the saw mill. *Weight* interferes with the lifting of the logs upon the truck or cars; *inertia* interferes with the starting of the car, and *friction* checks the running of the car. But without weight the logs would not stay on the car; without friction the car wheels would slip, and without inertia it would be hard to keep the cars in motion.

The axe is a *machine* (*inclined plane*); the logs are rolled with a bar (*lever*); they are hauled into the mill with a *pulley;* the lumber may be held together with *screws* and it may be hauled up into the building with a *wheel and axle*. Moreover, a *waterfall* may run the waterwheel which turns the saws, or *heat* in an engine may turn these saws. Hammers are *weights* which are used to do work.

Man can move or cause other things to move the factors of his environment in the work of building a house. He uses, changes, moves, combines, adjusts, and separates the forms of matter about him.

Remember that :

1. The environment of man is his workshop.
2. The chief work of men is the moving of matter from one place to another by the use of some form of energy.
3. The forces of gravity, friction, and inertia are the principal forms of resistance to any effort, although they are also aids to men in doing work.
4. The invention of simple machines by man has been the greatest factor in making his work easier.
5. The harnessing of the factors of his environment has been the chief means of developing the present age of industry and machinery.

THOUGHT QUESTIONS

1. Give two reasons why it is desirable to reduce the friction in the use of any type of machine.
2. Account for the fact that railway cars sometimes get a " hot box." How is this checked?
3. Why does bending a wire back and forth several times cause it to get hot?

4. Boys sometimes play " snap the whip " by getting in a long line, clasping hands, and running until the leader pivots and swings the line about him. What sometimes happens to the boys at the end of the line? Explain this.

5. How is the slipping of the wheels of a locomotive prevented?

6. What is the purpose of a brake? Explain just how one works.

7. Make a list of at least ten peculiar things that would happen if there were no force of gravity in the world; if there were no such property of matter as inertia; if there were no friction.

8. How is the force of gravity used to advantage in a meat market and in a grocery store?

9. Why is it easy to balance a moving bicycle?

10. Explain how pounding the end of the handle against a hard substance will drive a loose axe or hammer head on tight.

11. Explain why a sudden blow on the trunk of an apple tree will cause the ripe apples to fall.

12. A tallow candle has been shot through a board. Explain how this was possible.

13. Give two general and three special properties of the following: cork, glass, rubber, air, coal, asbestos, granite, aluminum, gold, quicksilver, iron, lead, sponge, copper, bricks, diamond, platinum wire.

HOME EXPERIMENTS

1. Place an upturned glass tumbler on the table. Place a smooth card on the tumbler. Place a coin on the center of the card. With the thumb and first finger, snap the card horizontally off the glass and note what happens to the coin. Explain this experiment to the class.

2. Test the following substances for their malleability: glass, copper, iron, a pin, brass, a small piece of stone, a wire nail, and a fine piece of lead. Report on your findings. What are the practical applications of your findings?

3. By the use of a Meccano or Erecto set, construct all the simple machines and put them to use in doing light pieces of work. Report on your work.

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Bachman. Inventions and Their Inventors. American Book Co.
Collins. Inventing for Boys. Nelson.
Collins. Book of Magic. D. Appleton and Co.

Gilbert. Manual for Toy Sets. A. C. Gilbert Co.
Holl. Home Handicraft for Boys. Doran.
Keene. Mechanics of the Household. McGraw.
Lynde. Physics of the Household. The Macmillan Co.
Morgan. Boy's Home Book of Science and Construction. Lothrop, Lee and Shepard Co.
Snow and Froeloch. A Hundred Things a Girl Can Make. J. B. Lippincott Co.
Williams. Something to Make. Nelson.
Williams. The Wonders of Science in Modern Life. Vol. 1. Funk and Wagnalls Co.
Wood. Something to Make. Funk and Wagnalls Co.
How to Make and How to Mend. By an Amateur. The Macmillan Co.

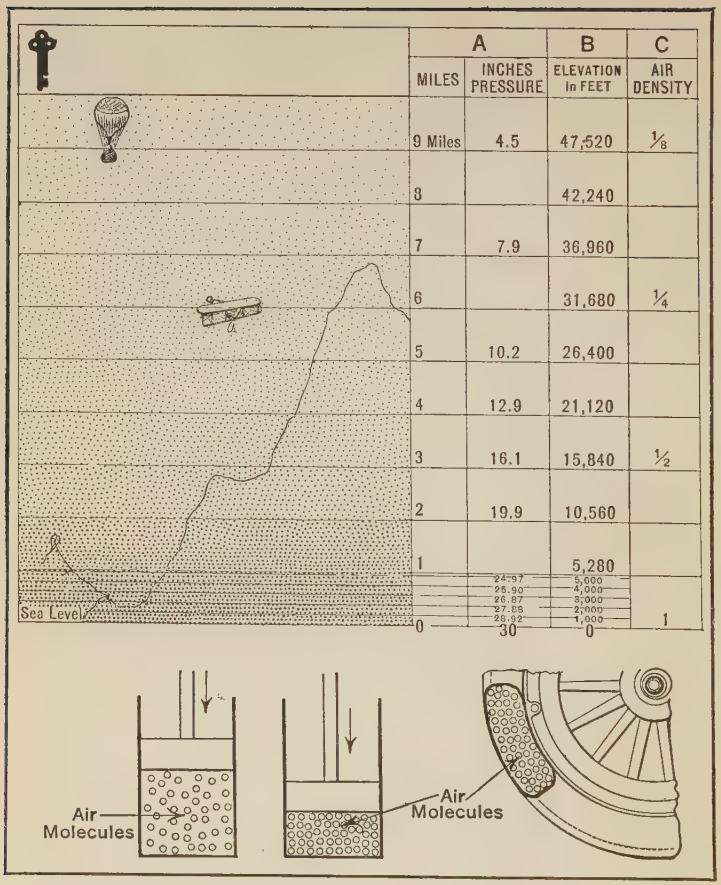
PART II

THE WORK OF THE FACTORS OF OUR ENVIRONMENT

When you call a thing mysterious, all that it means is that you don't understand it. — Lord Kelvin.

You have learned that your environment is most important to you because it gives you the things necessary to keep you alive. It is the source of your knowledge. It helps you to become a scientist. The work of science is to find new ways of using our environment for our own good. Since the greatest work of man is to move things about, science has found new ways of making this work easier for us. Science has invented simple and compound machines. Now, even air, water, heat, and falling bodies are made to give their aid in doing the work formerly done by the hand of man.

In the next few chapters your work will be to discover how air, water, electricity, and light all have power to do work for man. You will also discover some of the many ways in which the minds of men have been able to use these factors to make our lives richer and more comfortable.



KEY PICTURE 4. — ATMOSPHERIC PRESSURE AND COMPRESSED AIR.

The atmosphere becomes lighter in weight as one ascends a mountain. Why? Study the four columns on the right until you understand them thoroughly. Why will the balloon rise higher than the airplane? What happens to the molecules of air in a pump when the piston is pushed down? Explain how an automobile rides on air. Why does a tire "blow out" with a loud report?

CHAPTER IV

PUTTING AIR TO WORK

All Nature speaks in music — every tone
She utters, from the crashing thunder's roar,
Or Ocean's gush upon the rocky shore,
Down to the insect's hum, or light wind's moan,
Is full of harmony.

— Dryden.

What Do You Know about Air?

Do you suppose that air is a real substance? Do you believe that it weighs anything? Do you believe that it shows any pressure on the surface of a lake or upon the roof of your home? What would you think if you were told that air could do work? When you hear an automobile horn, have you any reason to suppose that air has anything to do with it? Have you ever noticed that when you are half a mile or more away from a locomotive you see the steam coming from its whistle long before you hear the sound? Does the air about you help you to hear sounds?

Some Practical Questions:

1. Why will a rubber ball full of air return to its original shape after its side is pressed in?
2. Why will bubbles arise from a bottle when it is suddenly placed under water?
3. Why will the palms of our hands tend to stick together if they are firmly pressed against each other? Try this and explain it.

4. You require about 600 cubic feet of air an hour. Does your classroom provide this amount? Assuming that the air is completely changed three times a period, multiply the cubic contents of the room by 3. Divide this product by the number of pupils.

5. If air cannot be seen, how can it hold up the weight of an automobile?

Home Problem. — As your mother washes the glass tumblers in hot water take one and set it bottom up on a piece of oilcloth. After half an hour examine the oilcloth through the glass and describe what has happened to it. Then lift the glass. Explain what happened and why it happened as you observed it.

Field Problem. — Blow into a paper bag until it is filled with air and then tightly close it. Have a companion take the bag about 300 feet away and burst it by striking it hard with his hand. Did you see and hear the bag burst at the same instant? Can you explain just what happened?

PRACTICAL QUESTIONS

From now on near the beginning of each chapter you will find a number of Practical Questions which have a direct bearing upon the chapter which contains them. By answering these questions you do two things for yourself. (1) You become familiar with some of the ideas to be discussed in the chapter. (2) You become interested in the useful facts of science because of their close relation to your everyday life. Make these questions a real test of your ability to think and to get answers to problems you have never met before. Here will be a good chance to surprise your teacher, your classmates, and yourself by your power to find out new things.

1. Air Is a Form of Matter

49. Air Is Real. — What would happen if the air ocean in which you live suddenly vanished? All fires would go out, extremes of temperature would prevail, and there would be no winds and no sounds. Death would come

almost immediately to practically all living things. The earth would be a barren, lifeless, silent desert.

50. What Is Air? — This looks like a very simple question and one easily answered. If you asked someone who knows about it, that would be a quick method of getting an answer, but you would be accepting the authority of another. Besides, he might not be right. To answer the question in a scientific manner requires time and experiment and close observation. As a scientist, you can well afford to use the methods of a scientist in finding out some real facts about air. Do you, for example, think that an "empty" glass is really empty?

Suggested Experiment. — Secure a glass tumbler, a basin or shallow dish two-thirds full of water, and a flat cork. Float the cork on the water, invert the tumbler over the cork and press it down into the dish of water until its edges touch the bottom. Does the water fill the tumbler? How far up in the glass is the cork? Can you tell what keeps the water out? Is this visible? Carefully record all your observations in your Science Discovery Book. Does air occupy or does it not occupy space?

Would your conclusion to this experiment lead to another question? If air occupies space, does it weigh anything?

Suggested Experiment. — Secure a football bladder, a bicycle pump, a metal air clamp or a piece of fine, strong cord, and a beam balance. Inflate the bladder with the pump, compressing the air, and close it with the metal clamp or the cord. Then hang the bladder on one arm of the balance (which should be suspended from a support so that it will swing free) and exactly balance the two arms of the scales so that the beam is in a horizontal position. Do this by placing small stones or sand in the pan opposite the one to which the bladder is attached. Now loosen the clamp or string, allowing the air to escape from the bladder. What happens to the arms of the balance? Can you account for this result? What is your conclusion? Does air have weight? What, then, may you call air? Give your reasons.

51. The Air Ocean. — Air occupies *all* space near the earth not filled by solids, liquids, and other gases. It even fills all the spaces between the particles in bread, wood, cast iron,

water, etc. It fills every room in your house. As a matter of fact, you walk about at the bottom of an ocean of air. The Atlantic Ocean is only a few miles deep, but the ocean of air above and about you, called the *atmosphere*, is from 100 to 500 miles deep. (Key Picture 4.)

Taylor Instrument Company.

FIGURE 25.—A TWISTER.

Note the funnel shape of this tornado. Note the black spot at its base indicating flying objects. It revolves at a terrific rate of speed. It also moves across country at a rapid rate.

Currents are found in the ocean which show that the water moves about. In the same way the air ocean has currents of air. Air has enormous force when in motion and may do tremendous work. A reading of the following newspaper clipping will show this:

MARCH TORNADO THE WORST YET

Some of the peculiar actions which showed its terrific power are illustrated in the fact that:

A rural schoolhouse was carried away, leaving the floor and the seats to which the children clung.

A chicken was plucked of every one of its feathers, but remained alive.

A horse was blown 900 feet.

A pair of trousers with $95 in one of its pockets was blown 39 miles.

A board was driven straight through a tree.

—*New York Times*, June 11, 1925.

52. Air Has Weight. — Air has this property in common with rocks, water, ships, houses, engines, clothing, and other things familiar to you. But in comparison with them, air is very light indeed. A cubic foot of air weighs from 1–1¼ ounces. A room of average size will contain from 100 to 200 pounds of air. It presses down upon substances because it weighs something and it weighs something because gravity pulls it toward the earth just like any other matter.

KEY DEMONSTRATIONS

Certain demonstrations in this book are marked "Key" because they are especially important. They unlock many ideas. All such demonstrations will have pictures and you will know them at once by the small key placed in the upper left-hand corner of the picture. When you see this sign it always means that you have a lock to open and a key to open it with. You must know these keys thoroughly because the whole discussion of the chapter depends upon them. If you fully understand these keys, the rest will be easy. Therefore, take special care in observing the key demonstrations and in writing them out in full in your Science Discovery Book.

You will find that some of the demonstrations are composed of several parts, but that all parts illustrate the same general principle. In such demonstrations it is not necessary to show more than one part, but in case more than one part should be shown, be careful to keep each one distinct in your mind. You may well label them A, B, C, etc., as below, or Step 1, Step 2, Step 3, etc. Try this method and see if it does not help you.

(Key) Demonstration 4: ***Problem: Does the air exert pressure upon the surface of objects (matter)?***

A. Materials: A two-quart empty varnish can; a tight-fitting rubber stopper; iron tripod; Bunsen burner; and a pint of water (Fig. 26).

Method: After pouring the water into the can, arrange the materials as shown in the diagram. When the water boils freely and much steam comes from the can, insert the stopper tightly and *immediately* remove the flame. Watch what happens.

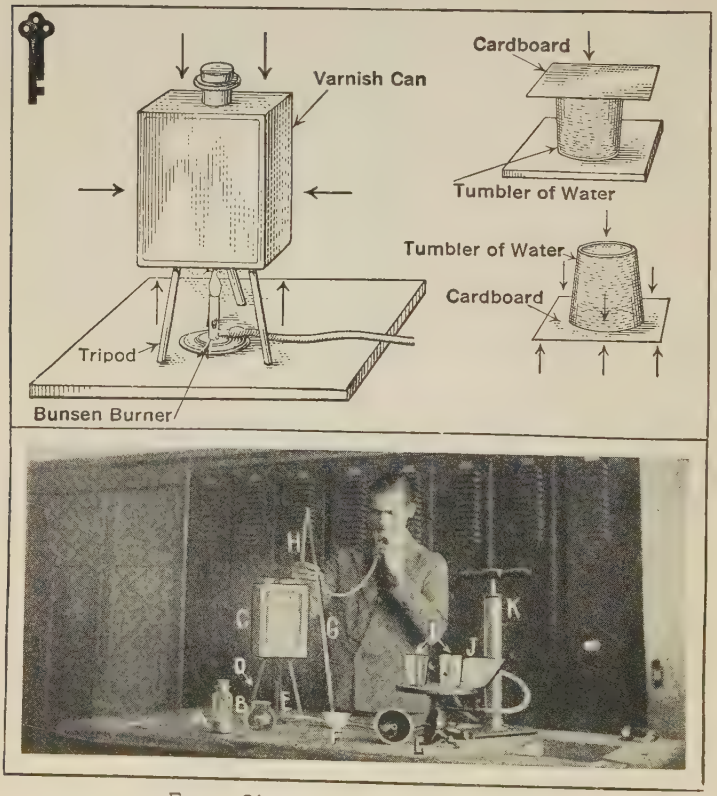


FIGURE 26. — (KEY) DEMONSTRATION 4.

A, mercury; **B**, palm glass; **C**, varnish can; **D**, tripod; **E**, Bunsen burner; **F**, shallow dish; **G**, glass tubing; **H**, rubber tubing; **I**, glass tumblers; **J**, cardboard; **K**, exhaust pump; **L**, Magdeburg hemispheres.

B. Materials: Glass tumbler of water and piece of smooth cardboard 6 inches square (Fig. 26).

Method: Place the cardboard firmly on top of the tumbler and, holding it tightly in place with one hand, slowly invert the tumbler

with the other hand. Now slowly remove the hand from the cardboard. What happens? Turn the tumbler to a horizontal position. What occurs?

C. Materials: A small bore glass tube about 30 inches long; a one-foot piece of rubber tubing to fit the glass tube; and mercury in a shallow dish (Fig. 26).

Method: Stand on a high stool, fit the rubber tubing to one end of the glass tube, place the end of the glass tube in the mercury, place the free end of the rubber tubing in your mouth, and draw in with your breath as hard as you can. Watch the mercury. Also watch the rubber tubing. Account for what you see. Why does not the mercury go to the top of the glass tube?

D. Materials: Palm glass; Magdeburg hemispheres; and exhaust pump (Fig. 26).

Method: Place the palm glass on the exhaust pump plate. Cover the glass with the palm of the hand. Exhaust the air from the glass. What happens? Now attach the hemispheres properly assembled to the exhaust pipe in the pump plate. Exhaust the air. Have two pupils try to pull the hemispheres apart. Note the result.

Observations: Record clearly just what you saw happen in *A*, *B*, *C*, and *D* above.

Conclusion: What is your conclusion? Give full reasons for your answer.

Practical Applications: Make a list of some ways in which air is used in a practical way by man or is made to do work because it has weight, occupies space, and presses upon surfaces. Write out this demonstration *in full* in your Science Discovery Book.

53. Atmospheric Pressure. — Pressure is the action or thrust of some force or substance against some definite area, which may be a square inch, square foot, or other convenient surface. When a book or brick is laid upon the hand, pressure is felt, due to the weight. Air, also, exerts pressure upon every surface it touches. Why?

The surprising bit of work on the varnish can was done by a form of matter which you cannot see, and cannot feel unless it is in motion.

54. Atmospheric Pressure Differs. — If you take ten apple pies and pile them one above the other, the bottom pie will at once be crushed to pieces, the fifth one from the top will

be pressed out of shape, while the next one to the top will show no signs of pressure. Explain this. So in the atmosphere, the lower layers receive the most pressure, and each layer, say each 1000 feet of air, as one goes up a mountain, receives less pressure, until at 3 miles up it is but half what it is at sea level. For this reason, airplanes and balloons cannot go beyond a certain height. Explain this. (Key Picture 4.)

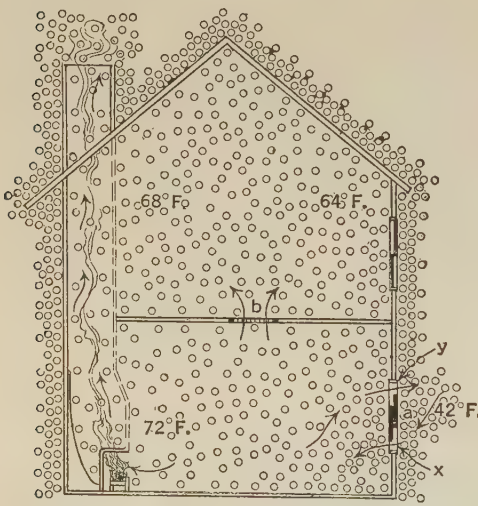
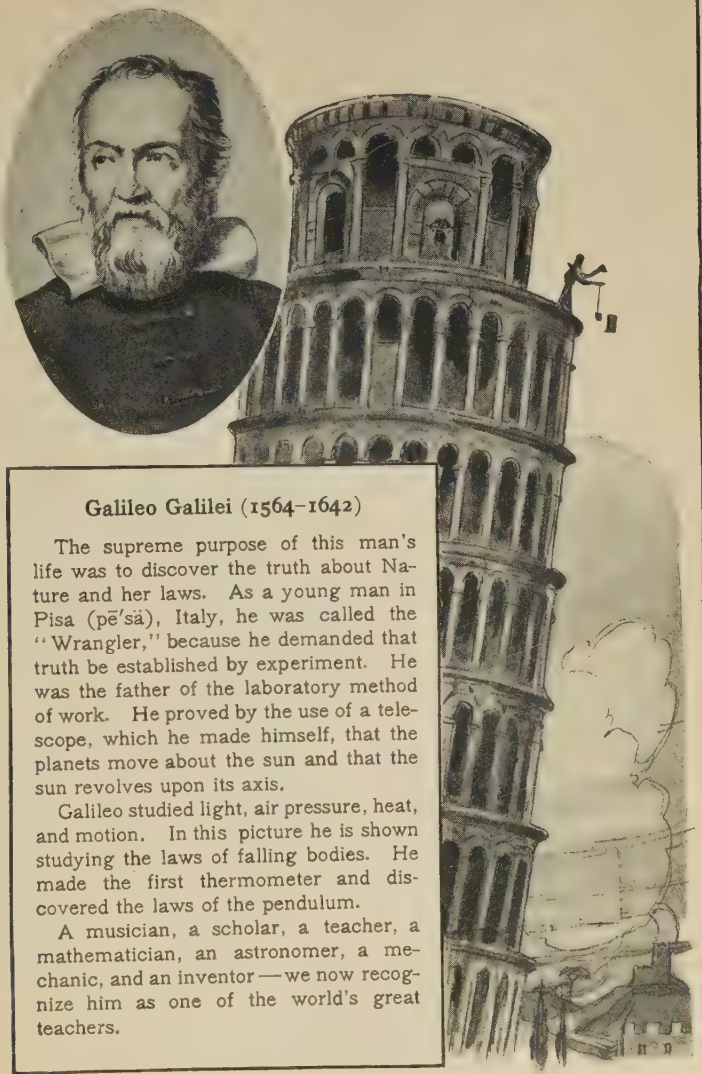


FIGURE 27. — AIR CONDITIONS INDOORS AND OUT.

If the small circles represent air particles, why are they closer together outside than inside the house? Why farther apart in the chimney than in the room? Why do they rise through the register at **b**? Why do they go out the window at **y**? Why do they enter the window at **x**? Why are they closer together near the walls than in the center of the room? Explain fully.

Again, it is known that warm air, volume for volume, is lighter than cold air. That is, a cubic foot of warm air weighs less than a cubic foot of cold air. Warm air, therefore, exerts less pressure than an equal volume of cold air. The reasons for this will be fully explained later. (Fig. 27.)

55. Measuring Atmospheric Pressure. — In 1640 the Duke of Tuscany dug a deep well and fitted it with a pump, but he could not make the water come up the pump barrel (Fig. 32) more than 34 feet, though he knew that he had a vacuum in the barrel of his pump and that Nature always tries to fill a vacuum. Why would



Galileo Galilei (1564–1642)

The supreme purpose of this man's life was to discover the truth about Nature and her laws. As a young man in Pisa (pē′sä), Italy, he was called the "Wrangler," because he demanded that truth be established by experiment. He was the father of the laboratory method of work. He proved by the use of a telescope, which he made himself, that the planets move about the sun and that the sun revolves upon its axis.

Galileo studied light, air pressure, heat, and motion. In this picture he is shown studying the laws of falling bodies. He made the first thermometer and discovered the laws of the pendulum.

A musician, a scholar, a teacher, a mathematician, an astronomer, a mechanic, and an inventor — we now recognize him as one of the world's great teachers.

Popular Science Monthly.

the water not rise in his pump more than 34 feet? The Duke took his problem to Galileo (gä'lē-lā'ō), the great Italian scientist, who told him that Nature did not "abhor that part of a vacuum" which extended above 34 feet. Galileo was too old at that time to experiment himself but he was still a real scientist. He at once turned the problem over to his brilliant pupil, Torricelli (tŏr'rē-chĕl'lē), for solution.

You are now going to do the same experiment that Torricelli did, in order to find out whether atmospheric pressure can be measured. It is well to note first, however, that Torricelli knew that water could be made to go up 34 feet in a pipe from which the air had been drawn. He got some mercury and found that it weighed 13.6 times as much as an equal volume of water. It was possible then that a column of mercury would rise or remain in a vacuum tube 1/13.6 as high as a volume of water of equal weight, or about 30 inches. He tried this with astonishing results.

(Key) Demonstration 5[1]: ***Problem: Can atmospheric pressure be measured?***

Materials: A thick-walled glass tube with $\frac{3}{16}$" bore, about 3 feet long and closed at one end; a shallow porcelain dish 3 inches in diameter; enough mercury to fill the tube and, also, to nearly fill the dish; and an iron ring stand with iron clamp.

Method: Carefully fill the tube with mercury, using a paper funnel for the purpose. Placing the thumb or first finger tightly over the open end of the tube, invert it in the dish of mercury and then slowly remove the thumb or finger. Fasten the tube in an upright position by the use of a clamp and ring stand so that the bottom of the tube does not touch the bottom of the porcelain dish (Fig. 28).

Observations: Observe carefully anything that happens and answer the following questions: What happened to the mercury? Note the space in the tube above the mercury. What caused the formation of this space? Is there any air in this space? This space is called Torricelli's vacuum. Why? Now measure the column of mercury from the surface of the mercury in the dish to its top. Record this height. If you happen to be near sea level, it ought to be about 30 inches high. This was exactly the result that Torricelli obtained.

[1] You will find that the difficulty of handling the apparatus in this demonstration makes it necessary for the teacher to perform it or at least to help you perform it.

Conclusion: What kept the liquid from running out of the tube? Can atmospheric pressure be measured? How?

Practical Application: Observe a barometer for several days and notice if the column of mercury differs in height on successive days. Can you now account for these changes?

56. Torricelli's Conclusions. — This great scientist at once saw from his experiment that the weight of the atmosphere was sufficient to support a 30-inch column of mercury or a 34-foot column of water in a vacuum tube of any diameter. He concluded that the weight of the atmosphere pressing down upon the mercury in the dish just balanced the weight of the mercury in the tube. In fact, the air was the effort and the mercury in the tube was the resistance in a lever (Fig. 28) and as the amount of the effort changed, the amount of the resistance changed also. Finally, he weighed a 30-inch column of mercury one square inch in cross section and found that it weighed just 14.7 pounds, or in round numbers 15 pounds, at sea level. So a column of air as high as the thickness of the layer of atmosphere above the earth and one square inch in cross section weighs about 15 pounds. Does it weigh more or less on top of Mt. Everest? Does it weigh more or less on the shores of the Dead Sea? Explain.

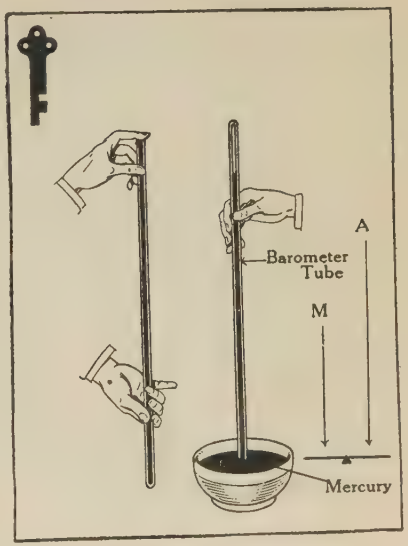


FIGURE 28. — (KEY) DEMONSTRATION 5.

Can you see why the conditions in this experiment resemble a lever? What is the effort? What is the resistance? What is the fulcrum?

Pascal, a French scientist, repeated Torricelli's experiment and also reasoned that if one went up a mountain with a 30-inch column of mercury, it ought to become shorter as one went on up. This theory was tested and found to be true. The mercury sank about 3 inches in going up about 3000 feet, or about 1 inch for each 1000 feet. (See Key Picture 4.)

So Torricelli found out what held the water up to 34 feet in the pump of the Duke of Tuscany and why it would not rise any higher. Can you tell why?

57. The Mercurial and Aneroid Barometers. — The common mercurial barometer is really a Torricellian tube,

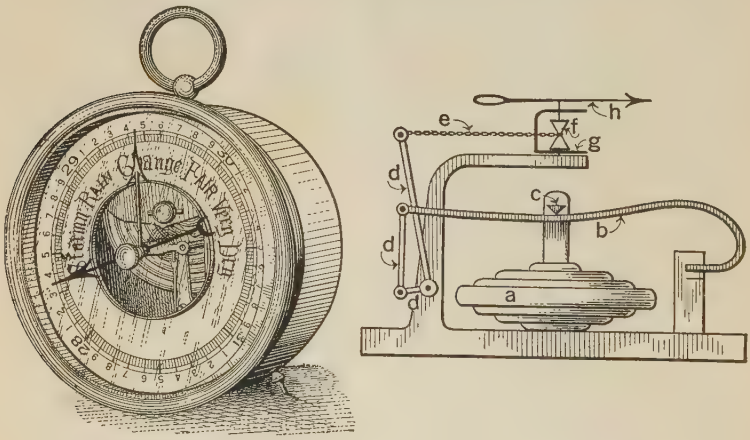


FIGURE 29. — EXTERIOR AND INTERIOR OF THE ANEROID BAROMETER.

Find out the use of each hand. The darker one varies; the other never does. What effect will the atmospheric pressure have on the drum at **a**? How will this affect **c** and **b**? How will this act upon **d**? How will **e** be affected? What will happen to the spool **f**? How will this affect the hand at **h**? What is the use of **g**? What machines are shown here? What makes them work?

filled with mercury with an extra supply in the bulb at the bottom and mounted on a board properly scaled to measure the height of the mercury column. What is the value of the extra supply of mercury? What does a mercury column greater or less than 30 inches mean to you? Explain. The

mercurial barometer is very accurate, but it is also a clumsy piece of apparatus. To determine altitude a portable mechanism must be used and so the aneroid (ăn′ĕr-oid) barometer was invented. It is a very delicate instrument and one easily put out of order. A study of the diagram (Fig. 29) will make its construction clear to you. Secure one of these barometers and measure the height of some high hill or two or three stories of a building with it. (Key Picture 4.)

58. The Barometer and the Weather. — The barometer indicates for us the atmospheric pressure at any given time and whether that pressure is becoming greater or less. A rising barometer means fair weather to come and a falling barometer means stormy weather, even though the sun is shining. Can you explain this? Your Key Picture will show you that the particles of air near the earth are closer together than up away from the earth. Why is this so? If particles of moisture in the form of water vapor (which weigh less than the particles of air)[1] force themselves in between the particles of air, the resultant mixture weighs less, volume for volume, than the original air. It therefore exerts less pressure on the mercury in the barometer bulb, with a corresponding drop of the mercury in the tube. (Air temperature, because it affects air pressure, also governs barometer readings, as we shall see on pages 455 to 459.)

2. Putting Air to Work

59. Atmospheric Pressure and Work. — A little thought will show you that you can use atmospheric pressure to do work by getting it to move things. You must, however, always set up the proper conditions. Just how you set up these conditions and how work is produced is very clearly shown in the ordinary lift pump.

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[1] The weight of 22.4 liters of water vapor is 18 grams; of 22.4 liters of dry air, 29 grams.

(Key) Demonstration 6: ***Problem: How does water rise in a lift pump?***

Materials: A medicine dropper; a small glass tube one foot long; a glass model pump or small glass syringe; and a glass of water. (Fig 30.)

Method: A. Insert the end of the dropper in the glass of water. Press the bulb. Allow the bulb to expand.

B. Insert one end of the glass tube in the glass of water and place the other end in the mouth. Blow through the tube. Now draw in the breath through the tube.

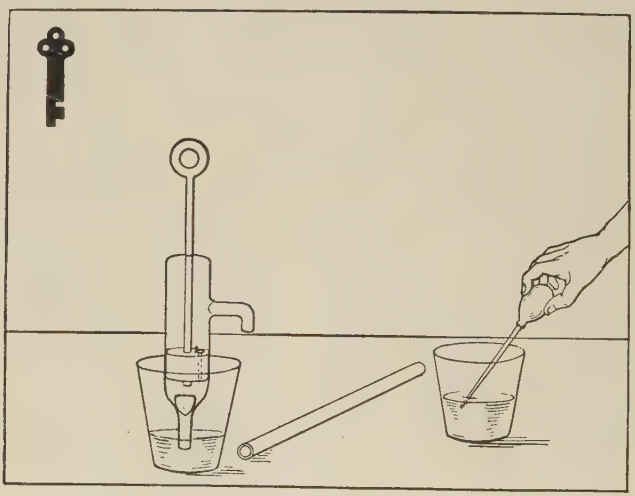


FIGURE 30. — (KEY) DEMONSTRATION 6.

In what ways are the medicine dropper and the glass pump similar? Note the valve in the pump. How does it work? When?

C. Place the lower end of the model pump or syringe in the glass of water. Work the piston slowly. Compare the results with what happened in *A* and *B*.

Observations: What filled the space in each piece of apparatus in the beginning of the demonstration? What happened to the contents of the bulb, tube, and pump or syringe as you followed out the directions under methods *A*, *B*, and *C*?

Is the air pressure inside and outside of the three tubes equal? Explain these conditions. Why does the water in the tumbler rise in each case? With what does the water correspond in Tor-

ricelli's experiment? Why is the water more active than the mercury? What is the use of the valve in the pump? What is the use of the piston? Does the water go out the same way it came in?

Conclusion: Write out in full your conclusion, giving reasons. Write up the demonstration in good form with drawings in your Science Discovery Book.

60. Lifting Water with Pumps. — Raising water from one level to another is hard work unless we make the factors of

FIGURE 31. — LIFTING WATER IN EGYPT.

Note the chain of buckets on the wheel at the right. The oxen have just passed between two vertical wheels. The one at the left engages with the big, horizontal wheel by a series of pegs and operates the bucket wheel through an axle. What kind of energy is here used?

our environment help us. In Egypt the treadmill and well sweep are still in use (Fig. 31). Where wells are in common use, as in the country, pumps are a necessity. Water seldom comes from a pump upon the first stroke of the handle. This is because there is no water in the pump barrel. A careful study of the accompanying diagrams (Fig. 32) will give the information needed to understand how a pump works.

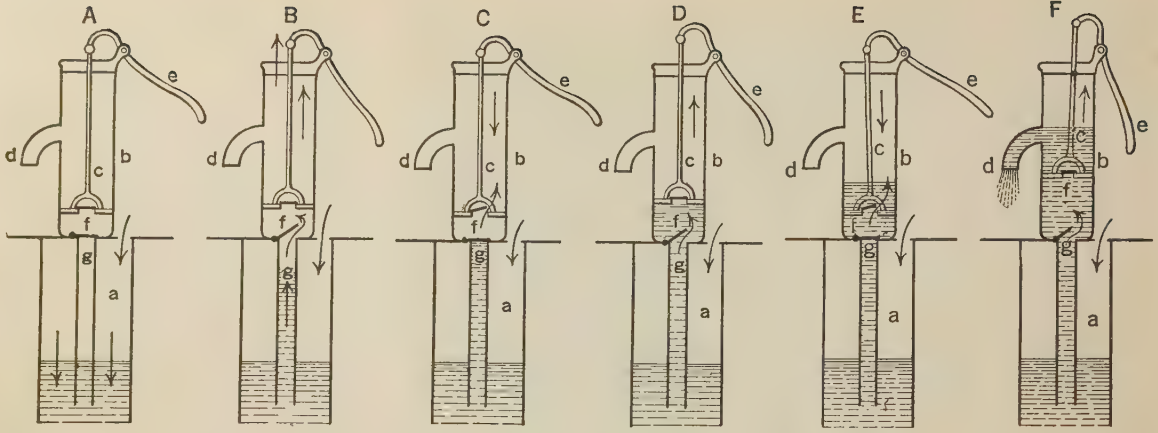


FIGURE 32. — STEPS IN THE ACTION OF A LIFT PUMP.

a, well; **b**, pump barrel; **c**, piston or plunger; **d**, spout; **e**, handle; **f**, piston valve; **g**, barrel valve.

1. What is the atmospheric pressure in the inlet pipe? the barrel? on the water in the well? 2. In **B** when the handle is lowered and the piston raised what happens to the air in the barrel? What effect does the raising of the piston have on the condition of the air in the barrel and inlet pipe below valve **f**. Study Key Picture 4 in answering this question. 3. What is actually formed in the barrel below **f**? 4. What effect does this condition have upon valve **g**? Explain. 5. Why does valve **f** remain closed in **B**? 6. In **C** why does valve **f** open? Why does valve **g** close? 7. What makes the water rise in the inlet pipe? Why does it stay at a certain level even after valve **g** is closed in **C**? Is the pressure of air equal in the inlet pipe and on the surface of the water in the well? Explain. 8. Explain why the water rises, why valve **f** closes and valve **g** opens in **D**. 9. What caused the opening of valve **f** in **E**? Why does valve **g** close in this condition? 10. What causes the opening of valve **g** in **F**? Why does valve **f** close? Why does the water run out of the spout in **F**? 11. What causes the steady rise of water in the inlet pipe and barrel? Give two reasons. 12. Describe in a complete story just how the pump works beginning with **A** and ending with **F**. What does the weight of the column of water in the inlet pipe and barrel exactly equal at the time it flows out of the spout?

Study the cistern pump in your kitchen (if you have one) or the pump in your yard and compare it with the one in Figure 32. If you have a chain pump how does it differ from this? Is the principle the same? Explain. (Key Picture 4.)

61. Sealing Jars. — The so-called "suction" or vacuum principle is used with success by the housewife in the sealing of jars. The fruit or vegetable is cooked and placed in the jars while boiling hot. Steam drives out most of the air. (Compare this with the condition in the varnish can just before the cork was put in place, page 76.) The rubber ring is then placed on the jar top and the cover screwed or otherwise fastened on (Fig. 35). What is the use of the rubber ring? The top soon becomes tightly fastened to the jar even before sealing. Account for this. What keeps the jar sealed? What must often be used to get the top off the jar when the contents are wanted for use? Explain. (Key Picture 4.)

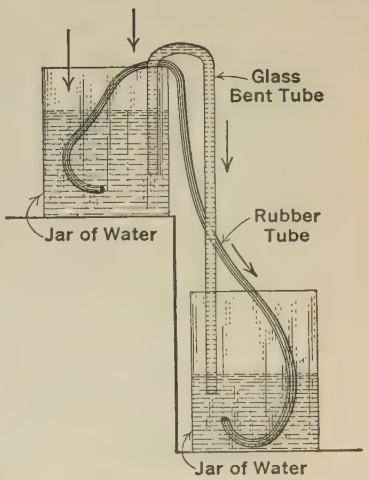


FIGURE 33. — THE SIPHON.

What do the arrows pointing down in the upper jar indicate? Could arrows be rightly placed in the lower jar also? What helps the flow of water downward through the two tubes?

62. The Siphon. — This is a simple apparatus which the ancient Romans, though well versed in engineering, did not know how to use. We now use it in our homes and in getting water to our large cities. What is its principle? Torricelli worked on this problem. He tried many schemes in order to find out why water goes up hill in a siphon. You can work an experiment at home and find out whether Torricelli was right or wrong in his explanation of this problem.

With suggestions from your teacher set up the apparatus shown in Figure 33 and see if you can make the water flow from the upper to the lower jar through the glass and rubber tubes.

63. Some Practical Uses of the Siphon. — As you have just seen, tanks of water too large to be easily moved can be emptied in a few minutes with the siphon. It will run the water from a washing machine to the sink, thus reducing the labor of wash day. Vinegar and other liquids may be drawn from barrels with this simple apparatus. But in every case the laws of the siphon must be fulfilled or it will not work. What are the laws of the siphon? (Key Picture 4.)

64. The Vacuum Cleaner. — The day of the broom is nearly past. Something more sanitary and efficient is taking its place and this is the vacuum cleaner. Upon what principle does it work? This you can find out for yourself.

Suggested Experiment. — Procure a glass tube 1 inch in diameter and about 6 inches long; a two-holed rubber stopper to fit the tube and to act as a piston; a small piece of muslin, a tiny square piece of rubber sheeting, some fine soil or sweepings, some shellac, and a stick to fit tightly one of the holes in the stopper. Secure a second stopper with one hole and a small piece of glass tubing about 3 inches long to fit tightly in this hole. Now fasten the piece of rubber sheeting along one edge over the second hole in the two-holed stopper by the use of shellac. Be sure that three edges are free. Then put the stick in the other hole so that the rubber sheeting which will act as a valve will be towards the long, free part of the stick and on top when the piston

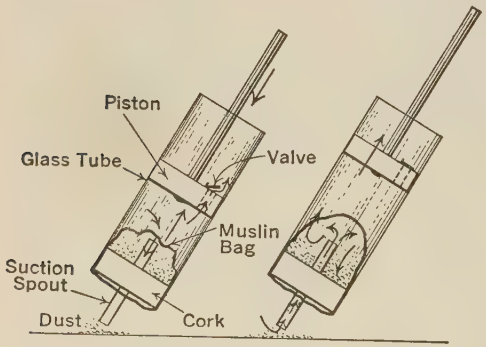


FIGURE 34. — HOW THE VACUUM CLEANER WORKS.

What makes the muslin bag fill out when the piston is raised? What happens to the dust then? Explain fully.

Evangelista Torricelli (1608–1647)

As a young Italian mathematician, Torricelli early attracted the attention of the great Galileo. One of Galileo's favorite pupils, he succeeded him in the chair of philosophy and mathematics at Florence.

Taylor Instrument Co.

Galileo, confronted with the problem of why water would not rise in a pump above a height of 30 feet (see sections 55, 56), turned the problem over to Torricelli. Torricelli shrewdly concluded that a column of water, 30 feet in height, exactly balanced the atmospheric pressure on the outside of the pipe containing the water. Then came into Torricelli's mind the idea that, since mercury weighed 13.6 times as much as water, volume for volume, a column of mercury but 30 inches high or 1/13.6 of 30 ft. would just about balance the atmospheric pressure outside of the tube containing the mercury. An experiment proved his theory to be right. How did this confirm his first explanation of the reason why water would not rise above 30 feet in a well? (He found the actual height of the column of water to be 34 ft., but friction and a poor vacuum had reduced it to 30 ft.) From this experiment came our present mercurial barometer. The great thing to remember, however, is that Torricelli reasoned like a real scientist and proved his theory to be true by true experimentation.

is in place. Next place the muslin over the other stopper and fasten it in place by pressing it tightly into the lower end of the glass tube. Insert the piston and press it downward. Compare your apparatus with Figure 34. Is it correctly assembled? Place the nozzle (small glass tube in lower stopper) over some of the dust on the table and raise the piston. What happens? Keep working the piston. Does the dirt disappear? Where does it go? Why does it go there? Does the atmosphere help here? How? Can the dirt get out? Why? Can the air in the glass tube get out? Where? How? How does the valve work on the piston? Explain fully how the vacuum cleaner works. Write it up in your Science Discovery Book.

The earlier vacuum cleaners consisted of a barrel and piston built exactly on the same plan as the little model you have just made and studied. But the modern cleaner is an electric portable machine. A rapidly revolving fan in a small metal box produces a good vacuum. The air rushes into this box and carries the dirt with it. Study any type of cleaner and report upon it. If you have none, send for a catalog of a good cleaner and study it. (Key Picture 4.) Report on its principle in class.

65. Drain Pumps. — Pipes leading from the sink to the sewer are sometimes stopped up with grease, lint, etc., and the plumber is often called in to remove the obstruction. Usually he places a rubber, bell-shaped cup over the sink outlet and by pressing down upon the handle attached to this cup he drives the air out from under it. Then by steadily pulling up on the cup, a very good vacuum is formed by which the obstruction is often removed. Explain. A simple cup of this kind can be purchased at any department store for less than a dollar and will pay for itself many times over in the course of a year.

66. Other Uses of Atmospheric Pressure in the Home. — You have considered fully a very few of the many uses to which atmospheric pressure may be put, due to its weight. Explain on what principle the articles shown in Figure 35 work and what their common uses are.

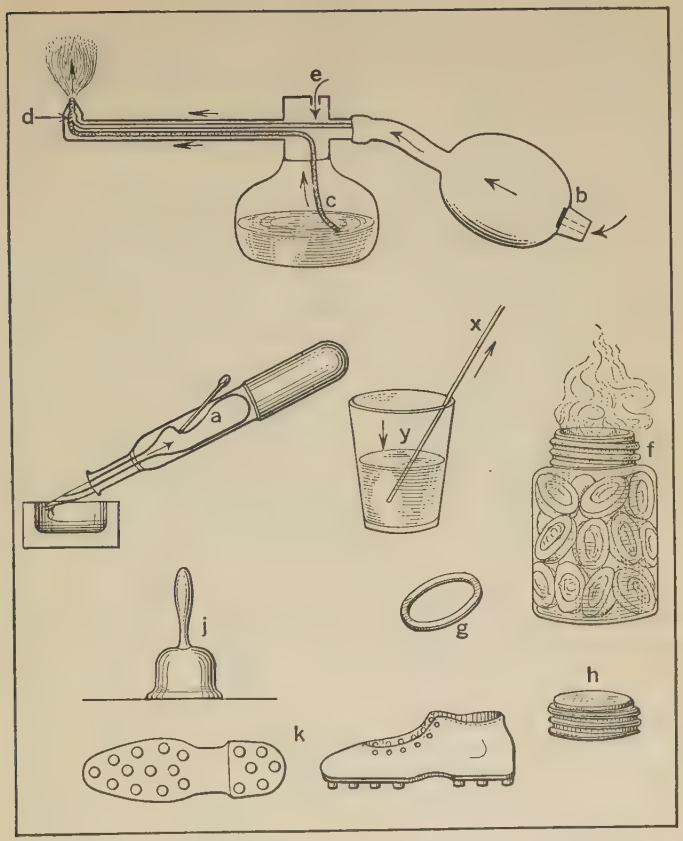


FIGURE 35. — SOME PRACTICAL USES OF ATMOSPHERIC PRESSURE.

In the atomizer when and why will the air enter the bulb at **b**? As it passes out at **d** it tends to form a vacuum in the tube **c**. Why does the air enter at **e**? What causes the spray? In the fountain pen, what effect does the lever have on the bulb? Why is the pen filled? In the canned fruit what does the steam do? the rubber ring **g**? the top **h**? What makes the shoes stick to the floor when being worn? How can you form a vacuum with the rubber bell **j**? These are used to clean out drain pipes. How? Explain the action of the air in the glass tumbler at **y** and the action of the water in the glass tube at **x** when one draws up with the mouth on the open end of the tube.

Non-skid automobile tires use atmospheric pressure. How? All cans containing liquids must have two openings in their tops to allow them to be easily filled and emptied. Why? Why must one hold a bottle with a small neck in a horizontal position to empty it easily? Why does water gurgle as it comes from a bottle?

67. Is Air Elastic? — A rubber band is elastic. You can stretch it and it will return to its original shape. Can the same thing be said of air? Can any gas be made to occupy a smaller space than it does where you find it? A demonstration will give you some facts about this question.

Demonstration 7: *Problem: Can air be compressed?*

Materials: A glass tumbler; a bicycle pump; a deep glass dish; a basket ball; a glass tube 1 inch long; and a gallon jar of water.

Method: Step 1: Fill the bladder of the ball with water. Pour some of the water from the bladder into the glass, filling it. Next empty the glass and fill it again from the bladder. Do this until the bladder is emptied, noting how many times the glass was filled with water.

Step 2: Now fully inflate the basket ball with air. As it becomes inflated feel of it and note its increasing resistance to the pressure of the hand. When full of air, tie the opening securely and strike the ball upon the floor. Does it rebound? Can you explain this?

Step 3: Fill the glass with water and invert it in the jar of water. Fasten the end of the glass tube securely in the end of the rubber outlet of the bladder. Then, holding the free end of this tube under the edge of the glass tumbler in the jar of water, loosen the string which keeps the air in the bladder, just enough to release sufficient air to drive out the water from the tumbler. As soon as all the water is out, stop the flow of air from the bladder, fill the glass again, invert it in the jar and drive the water out a second time. Repeat this process as long as the air will drive out the water, noting carefully the number of times this takes place.

Observations: After thoroughly discussing the demonstration, write out all your observations, determining if the volume of the air allowed to escape exceeds the volume of the water which filled the basket ball. How many times did the volume of air exceed the volume of water in the ball?

Conclusion: Is air elastic? Is it flexible? Can it be compressed? Give reasons for your conclusion.

68. What is Compressed Air? — You have been told that the air is composed of minute particles of gas. These particles are called *molecules* (mŏl′ē-kūlz). (Key Picture 4.) These molecules are so small that you cannot see them even with the microscope (mī′krŏ-skōp), but scientists know that they exist. No one can weigh one of them, but taken in large numbers they show weight, a cubic foot of air weighing about one ounce. These molecules as they are found in the air about you are not close together. But if you have an air-tight box with a good valve in it and attach an air pump to this valve and force more air into the box, you begin to crowd the molecules of air together. They press against each other and they press against the side of the box. If the sides of the box were rubber, they would bulge out under the pressure as in the basket ball bladder. In the box they are forced closer together. You now have *compressed air*. What is compressed air? (Key Picture 4.)

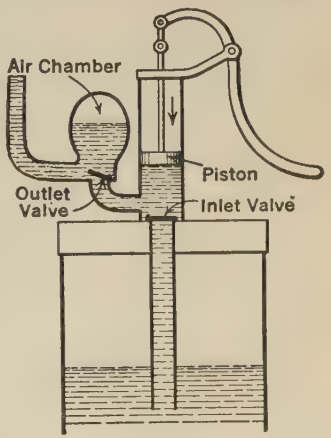


FIGURE 36. — THE FORCE PUMP.

Explain how atmospheric pressure is used in this pump (see Fig. 32). How and where is compressed air used here? When and why do the two valves work?

69. Some Common Uses of Compressed Air. — Our pneumatic (nū-măt′ĭk) bicycle and automobile tires, including the balloon type, depend upon the compression of air to make them of use to us. They make riding comfortable. How? Compressed air is used in the air brake to control and stop street cars and trains. It operates the cash boxes in great department stores. It operates many railroad signals, pushes mail through underground mail tubes in large cities, and is used in most of the whistles on electric cars and trains.

A common use of compressed air in the home and in public buildings is in the *door check*, which prevents the slamming of doors and insures their closing when opened. The check resembles a pump with cylinder and piston.

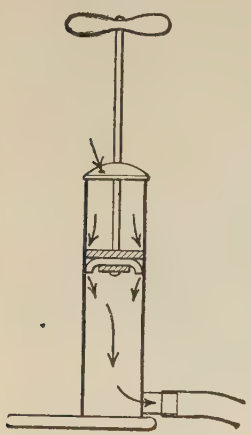


FIGURE 37. — THE COMMON AUTOMOBILE PUMP.

When the piston is raised what is formed below it? What will the air do above the piston? As the piston is forced down, the leather valve is forced up against the sides of the barrel. What effect does this have on the air below the piston? What happens now to the valve in the automobile tire? When will the valve again close? How does air get into the pump above the piston?

The *force pump* (Fig. 36) is now a common sight in or near the homes of persons living in villages or small towns. It always forces the water out in a steady stream, which would not be possible in the ordinary lift pump. Why? How does it differ from the lift pump? Force pumps are used in city water works where water must be pumped to the homes and in fire engines. Look for the air domes on the fire engine the next time you see it at a fire or examine it in the fire house.

Finally, the *air pump*, also called an *exhaust pump*, commonly seen in the school science room, is used in taking air from a chamber. The diagram in Figure 39 will give you the idea. Study it, answering the questions on it, and then describe how it works.

Special Problems. — Make a special study of the structure and working of the following pieces of apparatus and report your observations to the class:

1. An air gun. 2. A buoy. 3. A kite. 4. A pneumatic ink well. 5. A poultry fountain. 6. A vacuum cleaner. 7. A sand blast. 8. A pneumatic drill. 9. A Cartesian diver. 10. A sliding trombone.

70. The Caisson (kā′sŏn). — Piers for large bridges and the foundations of high buildings must be placed far down in

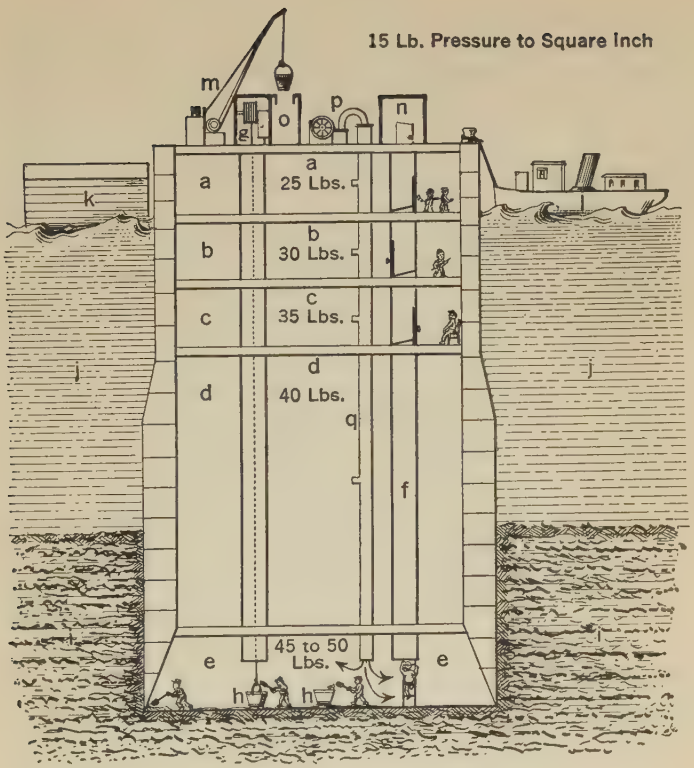


FIGURE 38. — THE CAISSON.

o, air lock; **a**, **b**, **c**, **d**, air chambers; **e**, working chamber; **h**, earth buckets; **p**, pump; **q**, air line.

1. What is the use of the different air chambers?
2. Why must there be protective coverings at **o** and **n**?
3. Note the door opening from **g** to **o**. Why is this necessary?
4. What does the 50-pound air pressure do in the air chamber?
5. How does it affect the men?
6. Why do the men have to rest in each chamber as they go up or down?
7. Account for the trap doors in the floor of each chamber.
8. How is the caisson increased in height as it goes into the mud?
9. What makes it go deeper into the mud?
10. The workmen cannot work long at a time in the caisson. Why?
11. What is the use of **f**? of **p**? of **m**? of **l**? What is shown at **i**, **j**, and **k**?

the earth on solid rock. But to go down to such depths always means the danger of caving in of the earth or of the rushing in of water. To do this work safely the caisson was invented. It is a tremendous air chamber filled with compressed air.

Suggested Experiment. — Attach a one-foot length of rubber tubing to the small end of an 8-inch glass funnel. Now invert the large end of this funnel in a battery jar of water. Does the water come up inside the funnel? How far does it come. Begin to blow through the stem of the funnel. What happens? Does the level of the water rise in the battery jar? Explain this and the principle of the caisson. Study Figure 38 and answer the questions.

3. How Air Helps You to Hear

71. Air and Sound. — Everyone has noticed that when a locomotive whistles some distance away, the steam can be seen coming from the whistle some seconds before the noise of the whistle is heard. What causes sound? How does it travel? How fast does it travel? What causes differences in sounds?

(Key) Demonstration 8: ***Problem: What has air to do with sound?***

Materials: A tuning fork; a glass of water; four test tubes all of the same size ($6'' \times \frac{5}{8}''$); a yardstick; an exhaust pump; a bell jar; and a cheap alarm clock (Fig. 39).

Method: A. Strike the tuning fork against the edge of the glass of water and then hold its prongs near the ear. Strike the fork against the glass of water and hold the ends of the prongs in the glass of water. Note results in each case.

B. Blow across the top of each test tube. Note results. Now fill one tube $\frac{1}{4}$ full of water, a second tube $\frac{1}{2}$ full of water, and the third tube $\frac{3}{4}$ full of water. Blow across the top of each of these tubes. Record results under observations in each case.

C. Strike the fork against the glass of water and then touch it gently to one end of the yardstick while the other is held near the ear. Repeat the process except that the end of the yardstick should be held this time against the front teeth. Record results.

D. Place the alarm clock, wound and set to ring at a certain minute, on the plate of the exhaust pump. Cover with the jar and exhaust the air. Note the clock at the time set for the alarm. Do you hear

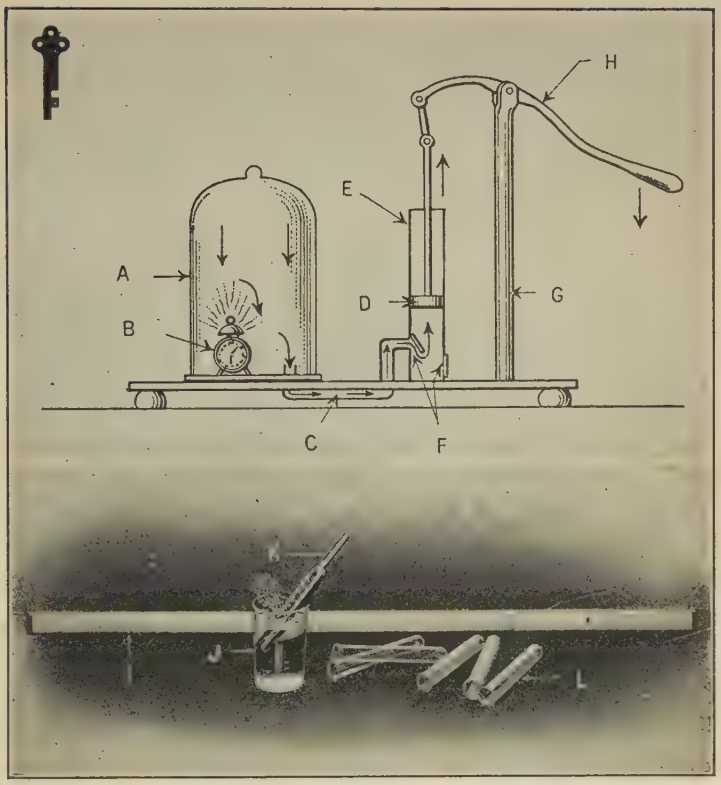


FIGURE 39. — (KEY) DEMONSTRATION 8.

A, bell jar; **B**, alarm clock; **C**, exhaust pipe; **D**, piston; **E**, cylinder; **F**, valves; **G**, support; **H**, handle of exhaust pump; **I**, yardstick; **J**, tumbler of water; **K**, tuning fork; **L**, test tubes.

Study the materials here used and tell how each part functions in the experiment. Explain the direction of the arrows in the bell jar and pump. Give the use of each of the parts of the pump.

the alarm? If you can hear the alarm faintly, allow air to enter the jar while the ringing proceeds. Record the result.

Observations: Record carefully everything you have observed in *A*, *B*, *C*, and *D* above, giving your reasons when possible.

Conclusions: Study your observations and then write as your conclusion the answers to the following questions:

1. What causes sound? 2. Do all vibrating objects produce the same amount of sound? 3. What causes differences in the intensity of sounds? 4. How is sound carried from one place to another? 5. Which is the best carrier of sound, metal, wood, or air? 6. What has air to do with sound? Write this demonstration complete in your Science Discovery Book.

72. How Sounds Travel. — Sounds are caused, then, by the vibration or rapid moving back and forth of some substance. The vibrations of the substance cause the air molecules to vibrate in ever widening circles or waves as when you throw a stone into still water. These air vibrations reach the ear and enter it. The ear drum (Fig. 43a) in turn vibrates, sending a sensation over a nerve to the brain, where the vibration is interpreted as that of a horn, piano, gun explosion, human voice, etc.

73. Sounds Differ. — The *pitch* of a sound depends upon the frequency, or distance from crest to crest, of the waves, its *loudness* upon the amplitude (height) of the waves, and its *quality* upon the nature and form of the sound-producing object. The more rapid the vibration, the higher the pitch. Vibrations ranging from 16 to 40,000 a second produce all the sounds we know, such as voices, bells, whistles, horns, musical instruments of all kinds, and the many sounds of nature.

74. The Speed of Sounds. — Sound waves travel at the rate of about 1087 feet a second when the temperature of the air is at 0° Centigrade or 32° Fahrenheit. As the temperature rises, the speed increases about 1 foot a second for every degree Fahrenheit and a little over 2 feet for each degree Centigrade. Knowing, then, what the temperature is at any time and place, it is possible to measure the distance across a small lake with a fair degree of accuracy. How

could this be done? How could one tell how far a thunder storm was distant from any given point by a similiar method?

75. Sounds and Music. — Sounds very familiar to you are those produced by musical instruments. Have you ever thought that much of the best music is produced by vibrating air, bells, and wires? You can prove this for yourself by a simple experiment at home.

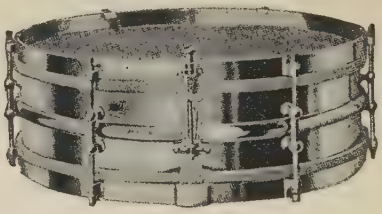
Suggested Experiment. — Procure a test tube, a G and an E mandolin strings, an ordinary dinner bell, a tack hammer, a policeman's whistle, and a pair of pliers. Blow gently across the open end of the test tube. What do you notice? Now blow harder. Upon what does the intensity of the sound you make depend? Upon what does its pitch (the note it corresponds to on the piano) depend? Now blow on the whistle. Compare the result with that obtained with the test tube. Determine, if possible, the cause of the irregular note of the whistle. Next attach an end of each of the mandolin strings to some strong support. With the pliers take hold of the other end of one string and pull upon it. As you continue to pull harder pick the string with your finger. Note the result. Do the same with the other string. Finally, hold the bell in one hand and lightly touch the edge of it with the tack hammer. Note the result. Strike harder. Now ring the bell. Account for the noise and its increasing volume. Can you now explain just how a bell, a whistle, and a wire give sound?

76. Musical Instruments. — Practically all music is produced by reinforced air vibrations due to the peculiar construction of the instrument producing those vibrations. This reinforcement is called *resonance*, and is generally caused by air waves entering one or more cavities and there vibrating with great intensity. The wooden sides of a bass or snare drum (Fig. 40) vibrate as well as the heads; the sounding board of a violin or piano also vibrates as well as the strings (Fig. 40). By this method a larger volume of air is set in motion and thus the volume of sound is increased.

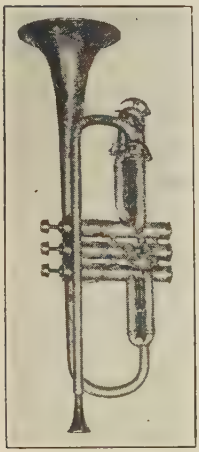
77. Pitch and Tone. — The pitch or fundamental tone of a stringed instrument is the sound produced when the whole string is vibrating. But there are minor vibrations called

overtones which are set up in different parts of the strings. These overtones give quality and richness to the sounds of an instrument. The pitch and tone of a string are determined by (1) its diameter, (2) its length, and (3) its tension. The

A. Violin.



C. Snare Drum.



B. Cornet.

D. Saxophone.

Oliver Ditson Company.

FIGURE 40. — MUSICAL INSTRUMENTS.

Indicate where the sound occurs in each instrument. Tell what causes it and how it is controlled and made into music.

What controls the pitch of the tones in **A**? in **B**? in **D**?

Can a drum be tuned? Why? What is the use of the hole in the side of the drum?

larger and longer a string is, the lower will be its tone. Explain. Tuning a piano is the art of properly adjusting the tension and lengths of the various strings so as to produce the proper fundamental tones.

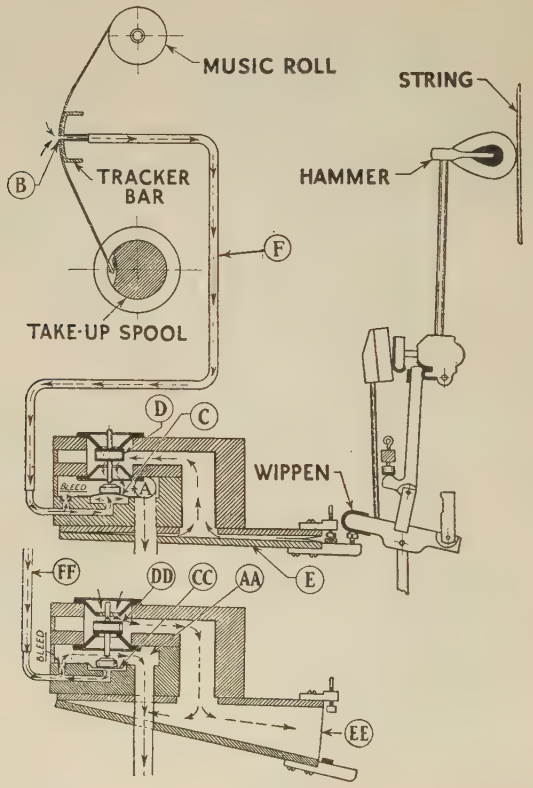
78. Wind Instruments. — In the flute, cornet, and piccolo, the breath is blown through a very small hole into an air chamber and resonant vibrations are set up. The pitch is controlled by stops and keys which when manipulated by the fingers either lengthen or shorten the column of air in the barrel of the instrument. In the horn the column of air is in violent vibration, the sound waves being modified and spread by the flare of the horn. The column of air between the mouth and the stops is lengthened or shortened by the keys and so the correct pitch is produced. Watch one of these instruments work and check its parts by use of Figure 40.

79. The Player Piano. — This instrument uses atmospheric pressure to produce action of the hammers upon the strings attached to the sounding board. A bellows connected with an exhaust pump is worked by the feet of the operator. Study Figure 41 and be able to explain it fully.

80. The Phonograph. — If you hold a knitting needle so that one end touches the head of a drum which has been struck, the needle will vibrate and the hand will feel these vibrations. If sound waves strike a disk to which a small needle is attached, this needle will vibrate. If this vibrating needle is lightly drawn across some soft material such as wax, impressions will be made in the wax. When hard, these impressions will again cause vibrations in a needle the point of which is passed over them. This needle can be attached to a vibrating disk called a *reproducer*. This in turn can be attached to a *resonator* (rĕz′ō-nā′tĕr) or horn, which magnifies the vibrations; we then interpret them as sound.

In the above description we have the fundamental principle of a phonograph. Study Figure 42 and answer the questions upon it and then examine a phonograph carefully.

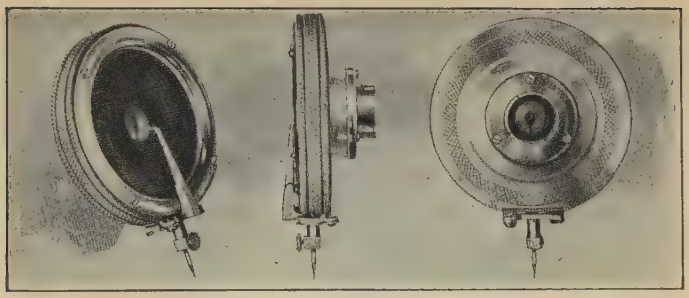
81. The Human Voice. — The human voice is a reed and wind instrument combined. At the top of the *trachea* (trā′kē-*ā*) or windpipe is a voice box called the *larynx* (lăr′-ĭŋks) or Adam's apple. Over its top are stretched thin



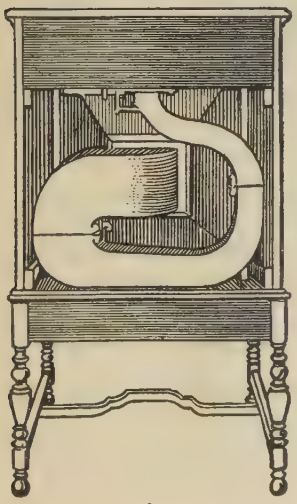
Aeolian Company.

FIGURE 41. — THE PRINCIPLE OF THE PLAYER PIANO.

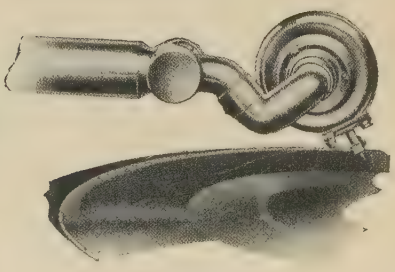
The pump forms a partial vacuum in the tube FF and chamber AA, by drawing air through the "bleed." This allows the air to pass over the valve DD to the bellows EE. When a hole in the music roll exposes a hole in a tracker bar, the air rushes down tube F, forces up the leather pouch at C, raises the valve at D, shuts off the air from EE, and opens the vacuum chamber at A. The air pressing on the bellows collapses it, the wippen is struck, and the hammer strikes the string.



B.



A.



C.

Sonora Phonograph Company.

FIGURE 42. — THE PHONOGRAPH.

A, the cabinet and resonator. Note the great length of this resonator. It is made of very light wood. Note its increasing size. Explain this. B, the reproducer. The needle is connected by an arm to the center of the dark mica reproducer. What passes over the needle? C, the needle in contact with the record. Note the hollow tube which connects the reproducer to the resonator.

projecting membranes called *vocal cords* (Fig. 43b). When you begin to speak, certain muscles stretch these cords and the air from the lungs rushing past them causes them to vibrate. Aided by the resonance of the bones, cartilage, and air spaces, they produce sound waves which we call the voice. The pitch and intensity of any voice depend upon the degree of tension of the cords, the force of the air passing over them, the length of the cords, and the configuration and control of the throat, nose, and mouth by the person to whom they belong.

4. Your Ears and How to Use Them

82. How You Hear. — If you look at your companion's ear you will observe that its flaring part looks something like a horn. This gives you the idea that it catches sounds. But this observation does not explain for you how one hears. You can get a clear idea of the mechanism for hearing by an experiment which you can work yourself.

Suggested Experiment. — Secure a baking powder can. Punch a small hole through the center of the bottom just large enough to push a stout cord through. Rub this cord with resin. Knot the end of the cord so that it cannot pull through the hole. Hold the open end of the can to the ear. Let a companion pull gently on the cord and then pick it with his fingers. Have this companion now slide the cord between his fingers, keeping it tight. Watch him and listen for results. Do you hear sounds in the can? How do they compare with the sounds when the can is held away from the ear? What causes the increase in sound? Study now a model or chart of the ear and determine what structure in the ear may be compared to the bottom of the can. What carried the sound from the bottom of the can to your ear? What structure of the ear tends to send sounds into it?

83. The Human Ear. — The ear is a wonderful contrivance for receiving and interpreting, with the aid of the brain, the meaning of air vibrations. The fleshy outer portion or external ear is so constructed that it catches and centers all air vibrations reaching it. Study Figure 43a and answer all questions upon it.

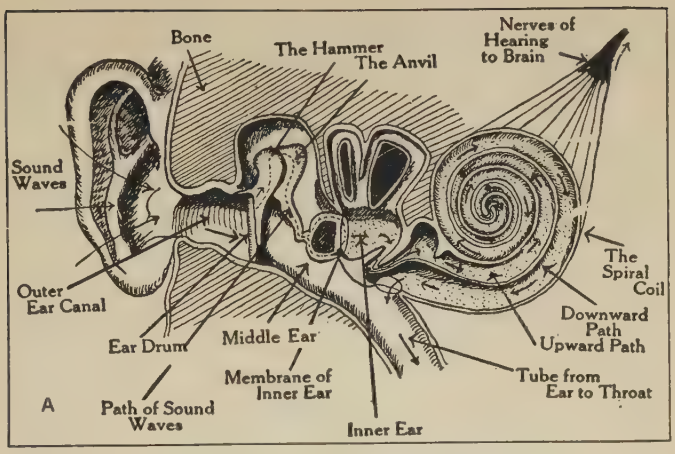


FIGURE 43A.—STRUCTURE OF THE HUMAN EAR.

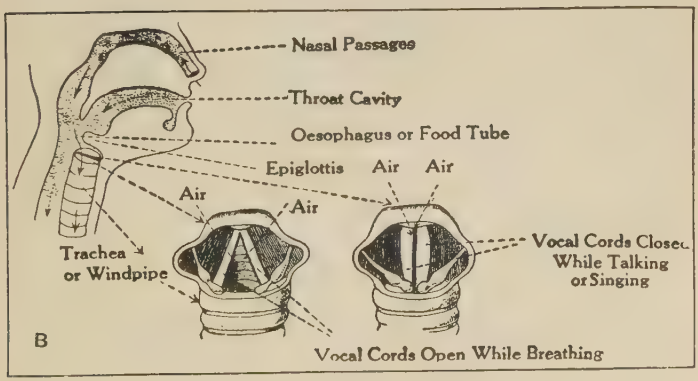


FIGURE 43B.—THE VOCAL CORDS.

Compare these parts to those found in musical instruments. Explain what the air has to do with the work of each organ. Why must there be a passageway to the mouth from behind the ear drum? Why must the vocal cords be controlled in their length?

84. Hygiene of the Ear. — Deaf persons are outside the circle of common conversation because it takes so much effort to make them understand. They are constantly in danger of being injured or killed and their culture is often sadly neglected. Explain.

It is very important, then, for you to understand some of the things you should and should not do in order to keep your ears in the best possible condition for hearing. Some rules follow:

(1) Never slap or "box" another person on the ear nor allow others to do this to you.

(2) Do not allow a large quantity of ear wax to accumulate in your external ear.

(3) Never attempt to remove this wax with a sharp instrument such as a pencil, toothpick, pin head, etc. Wax may be easily removed by twisting a part of a soft linen or silk handkerchief over the rounded end of a small hair pin and gently inserting it in the outer ear, slowly twisting it about. The wax will generally adhere to the cloth and so will be easily removed. If this treatment does not bring results, the family physician should be consulted. To remove foreign bodies from the ear, drop a little sweet oil in the outer ear. This will ordinarily float them into view and they can be easily taken out. In case this should fail, however, a physician should be consulted.

(4) It is well to cover the ears with a rubber cap when doing deep diving.

(5) Never sleep upon the ground without placing absorbent cotton in your ears. This is to prevent insects from crawling into your external ear.

(6) Never allow nose or throat trouble to go untreated. Go to a competent specialist to have it cleared up.

Now study the diagram of the ear and work out a definite reason for each rule for the care of the ear based upon its structure. You will understand better the value of these rules and the importance of following them.

85. Aids and Obstacles to Hearing in the Home. — Smooth surfaces are best adapted to stop and turn back sound waves without changing their form and rate of vibration. This is what we call *echo*. Conversation can be heard across water for great distances. Why?

In the forest the discharge of a gun produces a terrible crash and the echo reverberates again and again. Explain. In the open the report is sharp and short. Explain.

The rotunda of the Library of Congress and many halls such as the Mormon Tabernacle at Salt Lake City and the Open Air Theater at San Diego, California, with its immense organ and arched sounding board, make all sounds exceedingly distinct. Explain.

On the other hand, any room which is heavily furnished with draperies, carpets, curtains, pictures, furniture, etc., will cause an absorption of sound waves which might otherwise be reflected.

In the home, then, it is plain that the rooms should not be too high or too low, — about 8 to 9 feet on the average; the walls should be fairly smooth and pictures and furniture never too abundant or heavy. Neither should they be too few in number. Explain. The proper conditions will prevent the muffled voice or the harsh, hollow voice heard in some homes. Explain.

KEY WORDS

NOTE.— Remember to look back through the chapter for the following key words. Be sure to record the starred words in your Science Discovery Book.

air domes
air gun
aneroid barometer*
atmosphere*
atmospheric pressure*
atomizer*
barometer*
beam balance
bicycle pump
caisson*
Cartesian diver*
cartilage
compressed air*
door check*
drain pump*
Duke of Tuscany*
echo
exhaust pump*
external ear*
force pump*
Galileo*
kite
larynx*
lift pump*
Magdeburg hemispheres*
medicine dropper*
microscope
molecule*
overtone
Pascal*
pendulum
phonograph*
pitch*
pneumatic*
reproducer*
resonance*
resonator
sand blast*
siphon*
sound*
sounding board*

telescope*
tone*
Torricelli*
Torricellian tube*
Torricelli's vacuum*
trachea*
treadmill
trombone
tuning*
tuning fork*
vacuum*
vacuum cleaner*
vacuum cups
vaporized
vibration*
vocal cords*

REVIEW OUTLINE

1. Air is a real substance because it (1) occupies space and (2) has weight.
2. The air ocean (atmosphere) exerts pressure upon surfaces. This pressure (1) varies and (2) can be measured. Discoveries of Torricelli and Pascal.
3. Modern Air Pressure Instruments: (1) Mercurial barometer and (2) aneroid barometer. Use of each.
4. Atmospheric pressure does work in: (1) Lift pump; (2) sealing cans; (3) siphon; (4) vacuum cleaner; (5) drain pump; (6) medicine dropper; (7) syringe; (8) self-filling fountain pen; (9) atomizer; (10) tennis shoes; (11) tires.
5. Air can be compressed and made to do work in: (1) Automobile tires; (2) pneumatic cash tubes; (3) railway signals; (4) air guns; (5) door checks; (6) force pumps; (7) sand blasts; (8) sprayers; (9) atomizers; (10) caissons.
6. Air and Sound: how sound is produced. Sounds travel in waves; differ in pitch; differ in intensity.
7. Air and musical instruments, bells, whistles, and similar sound producers: how constructed to vibrate or cause vibration of air; importance of pitch and tone in each. The principle of the: (1) piano player; (2) phonograph; (3) human voice.
8. Sounds in Relation to the Human Ear: structure and work of the ear; hygiene of the ear; aids and obstacles to hearing in the home.

SUMMARY

The *atmosphere* forms a deep ocean over and about us. This atmosphere is a real substance because it occupies space and has weight.

Air presses down upon the surface of everything on the earth with a tremendous force. The higher up we go above the earth, the less is the pressure. We can thus determine altitude and forecast weather conditions with a barometer.

Atmospheric pressure can be used to do *work* for us by lifting matter, especially liquids, in lift pumps, drain pumps, syringes, medicine droppers, siphons, and vacuum cleaners, or in holding matter in place as in tennis shoes, non-skid tires, etc.

This same air can also be *compressed* into small spaces or containers; it thus exerts great pressure upon the sides of the container holding it. It is so used in automobile tires and in footballs, in caissons and in door checks. If compressed and suddenly allowed to escape in a certain way, air will do work in such contrivances as pneumatic mail or cash tubes, air guns, force pumps, sand blasting machines, and sprayers.

Sound is caused by a *vibrating body.* The air vibrates around this body, carrying the vibrations out in waves to the *human ear,* which is fitted to receive and to interpret these vibrations. All sounds differ in *pitch* and *intensity.* Some vibrating objects give us the sensation of sound which we call a *noise,* while other objects, such as the violin, clarinet, piano, and phonograph, give us sounds which we call *music.*

In order that the human ear may properly function it must be properly cared for and the home surroundings should be such as to aid the ear in receiving sounds.

Remember that :

1. Air is a real substance.
2. Air is valuable in determining altitudes, in forecasting the weather, in moving gases, liquids, and solids and in holding objects in place.
3. Air is elastic and can for this reason be made to carry loads, and move gases, liquids, and solids.
4. Air makes sound possible.
5. Sounds play a very large part in the pleasures and work of our lives.

Explain in full each of the above statements.

THOUGHT QUESTIONS

1. A paper bag, blown full of air, tightly closed, and struck a blow, bursts with a loud report. Account for the bursting and the noise.
2. Why is it that when a small amount of illuminating gas is released from a gas jet, it can be detected by its odor in the opposite end of the room?
3. Account for the fact that a person's nose may bleed when he is climbing a high mountain.

4. Why do dust and papers tend to fly after a rapidly moving automobile or train?

5. Why does it greatly tire one to walk in the mud?

6. Which would you prefer to carry a mile, an inflated or a deflated automobile tire? Explain.

7. If a person quickly opens a door on one side of a room, any other door in that room will also move, if unlatched. Explain.

8. The mercury in the Torricelli barometer is held up by the force of gravity which tends to pull things down. Explain this.

9. A gas-filled balloon will burst at high altitudes. Explain.

10. A drummer strikes the cymbals together in an orchestra and then immediately touches them with his hand. Why? Explain.

SPECIAL PROBLEM

Form a committee of from three to five of your classmates and test one another's hearing. Hold a watch about six inches from the ear of a companion, with his other ear covered. Can he hear the ticking of the watch? Place the watch at a distance of one foot. Can he now hear? If he can hear the ticks at a distance of eighteen inches his hearing is normal. In what two ways could the hearing be abnormal? Test the other ear in the same way. Is his hearing equally good in both ears? Test the others of the committee in the same way. How many have normal hearing? How many are above normal? below normal? What is the average hearing distance for the committee? Is it above or below eighteen inches? If defects are found, what would you suggest doing?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

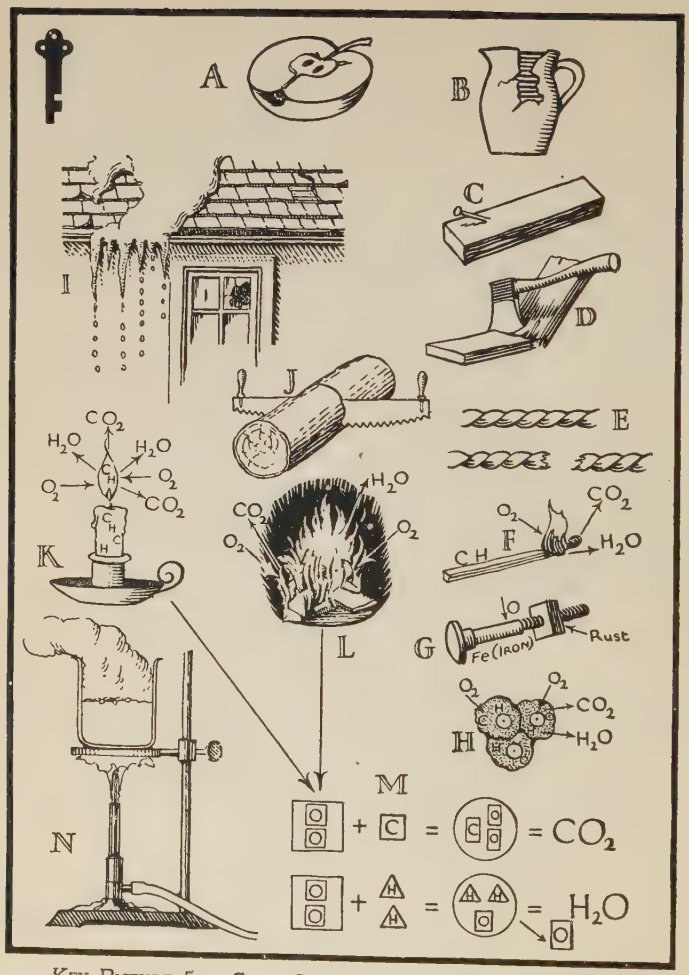
Bragg. The World of Sound. E. P. Dutton and Co.
Burns. The Story of Great Inventions. Harper and Brothers.
Cochrane. Wonders of Modern Mechanisms. J. B. Lippincott Co.
Darrow. The Boy's Own Book of Great Inventions. The Macmillan Co.
Gilbert. Sound Experiments. Gilbert Co., New Haven, Conn.
Houston. The Wonder Book of the Atmosphere. Stokes Co.
Mills. The Science of Musical Sounds. The Macmillan Co.
Tappan. Wonders of Science. Houghton Mifflin Co.
Taylor Instrument Co. The Barometer as the Footrule of the Air.
Taylor Instrument Co. The Barometer Book.

SPECIAL PROBLEMS

When you can start out with confidence to solve either at home or in school any of these special problems you are on the high road to success as a young scientist.

To handle these problems successfully, however, you must first have, as you probably have already discovered, a good working knowledge of all the facts and principles so far covered in the subject of General Science. Then you must deliberately begin to collect materials to work out your problem. In this you follow exactly the steps of a key demonstration. Having gathered the materials, you are to use them in a way to bring about some natural result. Using this as a basis you may draw a conclusion which may again be the basis for a second problem to be solved.

In working out these problems you must always be ready for new problems which may arise as a result of what you are doing. This is exactly what the true scientist always does. You may find several experiments necessary before you arrive at your general conclusion. But when you get this conclusion, you will derive great satisfaction from it. Do not fail, therefore, to secure all the information you can from all sources. This will all be helpful and valuable to you.



KEY PICTURE 5. — SOME CHEMICAL AND PHYSICAL CHANGES.

Study carefully the pictures at **A**, **B**, **C**, **D**, and **E** and determine what kind of change has taken place in each. How does each differ from those occuring in **K** or **F**? Study every part of **I** and tell two kinds of change occuring here. How many examples are there of each kind of change in **I**? How are the changes in **F**, **G**, **H**, **K**, and **L** alike? How do they differ? What can you say of **J**? of **N**? Now study the pictures at **M** and see how they explain just what happens at **F**, **H**, **K**, and **L**.

CHAPTER V

AIR, FIRE, AND LIVING THINGS

Around us Nature's laws are stretched afar,
And vast designs of Providence unseen.
Whither they lead we know not, but they are
Substantial to our touch, on them we lean.
—Ritchie Smith.

The work of science is to substitute facts for appearances and demonstration for impressions. — John Ruskin.

What Do You Think Makes Fire Burn?

Do you know why they throw water upon a fire to put it out? Would you believe the statement that all living things are slowly burning up? Did you know that your body must have good air in order to burn well so that you can be healthy and do good work? Would you be interested in finding out the best methods of getting this life-giving air into your home and school?

Some Practical Questions:

1. Why does a match light?
2. Why will a fire keep burning in a stove over night with all the drafts closed?
3. Fires in steamship holds have often been put out by blowing steam down into the interior of the ship. Explain.
4. Why does the human body need oxygen?
5. What is the importance of deep-breathing exercises?

Home Problems. — 1. Open the lower draft and close the feed-door draft in your furnace. Note the effect upon the fire. Reverse the process when the fire is lively and note the effect. Explain.

2. Light one of the burners of your gas stove. Place both thumbs over the vents in the mixer just back of the turncock and see what happens. Explain fully the results.

Field Problem. — If possible, visit the scene of a fire and watch the firemen work. Note the effects of the water on the fire. Explain why it is "put out." If the fire begins again where it was once "put out," explain it.

KEY PICTURES

You have already been attracted by the picture at the beginning of each chapter because it told you so many interesting things which were very helpful to you in studying the chapter.

This is just the purpose of these pictures. They give you an introduction to new chapters and sum them up for you. You will want to refer to them constantly in order to refresh your mind as to the central ideas of the various chapters.

Your key demonstrations show you fundamental principles necessary to the understanding of the text. The key pictures do the same thing, but in another way. They appeal to your eye and will help you over many a hard and difficult spot. Use the key pictures again and again. They will help you.

1. Why a Fire Burns

86. The Discovery of Fire. — We use fire so commonly to-day that it seems almost impossible to believe that there was a time when men did not know what fire was. No one knows when man first discovered fire or when he was first able to produce it. He certainly must have been surprised or even terrified at the first sight of it. Is it any wonder that savages worship fire?

87. Air and Fire. — Almost every boy and girl has asked the question: What makes fire burn? Do you know just what air has to do with the burning of the fire? A simple demonstration will give you an answer to this question.

(Key) Demonstration 9: ***Problem: Is air necessary to make things burn?***

Materials: Two small battery jars (C); two short pieces of candle (B); and a piece of heavy cardboard or sheet tin about 5 inches square (A).

Method: Place a candle upright in the bottom of each jar. Light both candles. While they are burning cover the mouth of one jar with the cardboard or plate. (Fig. 44.)

Observations: What happens in each jar? What filled both jars at first? Account for the different actions of the candles in the two jars.

Conclusion: Write out your conclusion, giving reasons.

Practical Application: What is the best way of making a fire burn? Can one give a fire too much air? What is the simplest method of "checking" a fire in a stove? How would you put out a small fire? Why does stepping on a match "put it out"? Why will blowing a smoldering fire often make it burst into flame?

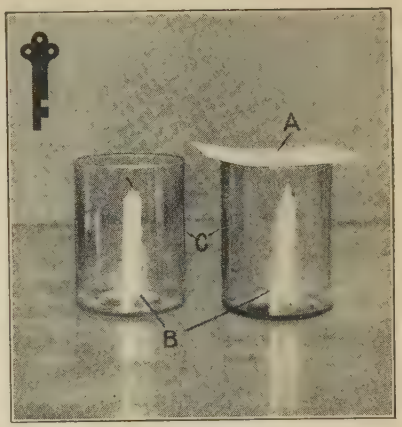


FIGURE 44. — (KEY) DEMONSTRATION 9.

Can you tell why two jars are used? Why are two candles used?

88. Of What Is Air Composed? — Since air is so necessary in burning, we ought to know the nature of this air. Here is a problem for you to solve by yourself. You can do this at home or in school.

Suggested Experiment. — Secure a small battery jar, a shallow dish of water, a small piece of phosphorus (see footnote on p. 120), a flat cork large enough to hold the phosphorus easily. Set the phosphorus on the cork and place the cork and phosphorus in the shallow dish of water. Touch a lighted match to the phosphorus. Invert the battery jar and lower it over the phosphorus and cork until its edges touch the bottom of the dish. Record what happens to the phosphorus, the cork, and the water in the shallow dish. What was in the jar at first? Why does the water rise in the jar? Why does it stop rising? Why did the phosphorus go out? About what part

of the whole jar does the water occupy? Does this experiment show that air is just one kind of substance or that it is a mixture of two or more substances? What are the relative amounts of each substance?

89. The Air and Fire. — You now know that a part of the air supports burning. But you do not know as yet what part does this work. A demonstration will make this clear to you.

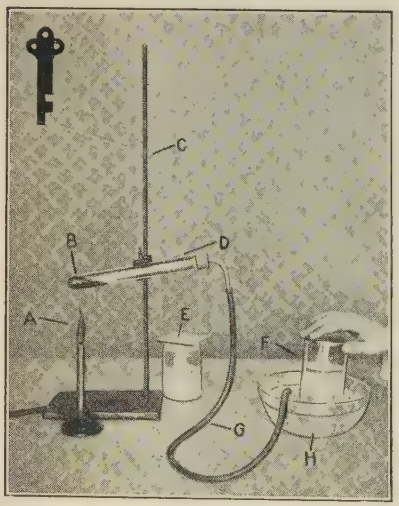


FIGURE 45. — (KEY) DEMONSTRATION 10.

A, Bunsen burner; **B**, mixture of chemicals in tube; **C**, iron ring stand; **D**, boiling tube; **E**, **F**, wide-mouthed bottles; **G**, rubber tubing; **H**, shallow dish containing water.

Can you tell why the long rubber tube is used? What does the heat do? Why is the bottle filled with water? Why does not the water run out when the bottle is inverted?

(Key) Demonstration 10: ***Problem: What part of the air makes things burn?***

Materials: An iron ring stand; a large test tube (1″ × 8″); a one-holed rubber stopper to fit the test tube; a rubber delivery tube about two feet long; two wide-mouthed bottles; wood splints; a Bunsen burner; a shallow dish; potassium chlorate; and manganese dioxide.

Method: Set up the apparatus as shown in Figure 45. Place in the large test tube about two tablespoonfuls of a mixture of equal parts of potassium chlorate and manganese dioxide. Apply Bunsen flame gently to end of test tube and collect the gas given off under the bottle in the shallow dish. These bubbles are composed of a gas called *oxygen*. When the water is entirely driven out of the bottle, remove the bottle and cover it with a glass plate. *Caution: Always remove the tubing from the water before removing the flame.* Now thrust a glowing splinter of wood into the bottle. Blow out the flame and thrust it in a second time. Try it again.

Observations: 1. What was in the bottle before the water was put into it? 2. What change occurred in the bottle when the water was put in? 3. What form of matter took the place of the water in the bottle? 4. Why did the water leave the bottle? 5. Did the splint burn brightly in the bottle? Why did the wood splint burst into flame? 6. Why does a candle burn in the air? Why does anything burn in the air? 7. Is oxygen an active gas?

Conclusion: What part of the air makes things burn?

Practical Application: Why will the closing of steel shutters on warehouses help to put out a fire in them? Why is it fortunate that only about $\frac{1}{5}$ of the air is oxygen? Why is the flame of an oxygen-hydrogen light so intensely hot?

90. Nitrogen. — While oxygen occupies about $\frac{1}{5}$ of the atmosphere, another gas takes up almost $\frac{4}{5}$ of the remainder. This gas is *nitrogen.* To find out one of its important properties you can work this simple experiment.

Suggested Experiment. — Use the apparatus of Demonstration 10. For materials use a small amount of ammonium chloride and sodium nitrite mixed. Gently heat the mixture in a test tube. Collect gas as before, remembering the caution! Place a burning match in the bottle. What happens? Try it again. What is a characteristic of nitrogen? Why is it fortunate that there is so much nitrogen about us in the air?

91. Carbon Dioxide. — You probably saw nothing come away from the wood splints as you burned them, but the fact that you cannot see a thing does not mean that it does not exist. Can you see air? Try a simple experiment and carefully note the results. You may be surprised at them.

Suggested Experiment. — Hold the flame of the candle under the mouth of an inverted bottle for a few moments. Note carefully the inside surface of the bottle and observe the water there. Now pour some limewater into this bottle and shake it well. What happens? Hold a lighted wood splint under a second inverted bottle. Do you note the same result as before? Pour in limewater and shake. What happens? Finally hold the lighted candle under a glass plate so that the flame almost touches it. What do you find on the plate? Use the burning wood splint in the same way. What happens? What gas made the candle burn? the wood splint?

How can you account for the water given off from the flames? What happened to the limewater in the bottle? *Note:* Chemists have discovered that the only gas known that will turn limewater milky is *carbon dioxide.* What, then, is the second product of a burning candle and wood splint? What is the black substance on the plate? We call this unburned carbon or soot. What are two products of the burning of wood or a candle?

92. Some Things Carbon Dioxide Can Do. — This substance is matter, just as carbon is matter. It must, therefore, have certain properties. You have already learned what it will do to limewater. This is a *chemical property.*

Suggested Experiment. — If you get a little hydrochloric acid, some baking soda or marble dust, a wide-mouthed bottle, a test tube, and a wood splint, you can determine some other properties of this substance. Place about 10 grams of the soda or marble dust in the bottle and pour over it some of the acid. Note what happens in the bottle. Did you feel any heat? What kind of energy is here shown? Thrust a lighted wood splint into the bottle. What happens? What is a second property of carbon dioxide? Smell the contents of the bottle. Has it any odor? Has it color? Can you see it? Give three other properties of carbon dioxide.

93. Why a Fire Burns. — Not until the year 1774 was it discovered that oxygen had considerable to do with fire. It had always been supposed that when a substance burned, something escaped from it.

But Lavoisier (lȧ′vwȧ′zyā′), a French scientist, found out that things actually gain in weight when they burn. This gain is caused by the addition of oxygen from the air during the burning process. Lavoisier also found out that not all of the air surrounding a substance was used up in the burning, because the burning would not go on long in an inclosure and there was always something left that " put out " fire. What is this gas?

On August 1 of the same year, Priestley, an Englishman, prepared oxygen by heating a red powder known as mercuric oxide. The powder disappeared and a gas took its place. A glowing splinter of wood, when placed in this gas, burst into a bright flame. He also put a live mouse in an inclosure containing this gas and it continued to live. This gas Priestley called " good air," which is the form of matter we now call *oxygen.* Lavoisier then called the gas which put out fire " bad air," which is the gas we now call

Antoine Lavoisier (1743–1794)

Popular Science Monthly.

This great French chemist was the founder of modern chemistry. After receiving an excellent education, he determined to devote his life to the cause of science. He proved that matter can be neither created nor destroyed, but his greatest work was his correct explanation of the process of oxidation. Using Priestley's discoveries as a basis of his work, he showed that a metal gains in weight when heated in the air. He named this substance which causes a gain in weight "oxygen" or "acid former." He named hydrogen and nitrogen also. He wrote the first text-book on chemistry.

We owe to him the methods of bleaching linen, of refining metals, of lighting by gas, of extracting sugar from beets, and of dyeing, and the fundamentals of the improved manufacture of steel.

Interested in politics, he unfortunately came into contact with the French Revolutionary government and was guillotined in 1794. In this rash act France lost one of the greatest men she ever produced.

nitrogen. He further decided that the air is made up of more than one gas.

The observations of these two men showed that it is the oxygen in the air which makes things burn and that most substances will not burn even in the presence of pure oxygen unless they are heated to a certain point called the *kindling* or *ignition* point. Then burning begins.

(Key) Demonstration 11: ***Problem: Do the kindling temperatures of some common combustible substances differ?***

Materials: A small lump of sulphur; a piece of phosphorus[1] (fŏs'-fŏr-ŭs) the size of a pea seed; an iron ring stand and clamp; a Bunsen burner or alcohol lamp; a small piece of writing paper; a small cube of wood; and a piece of sheet iron about 8″ square.

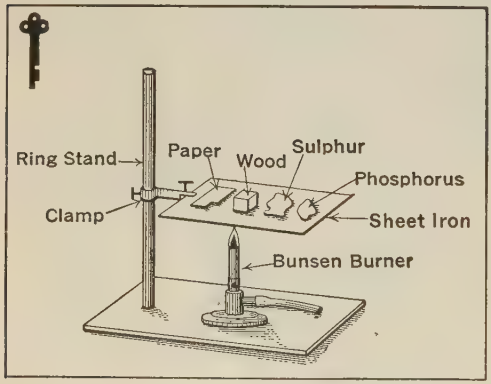


FIGURE 46. — (KEY) DEMONSTRATION 11.

Does the order in which the materials are placed on the plate make any difference in the results? Explain why one substance burned first and why one burned last. Account for the order in which they burned.

Method: Assemble the apparatus as shown in Figure 46. Place the four substances to be tested on the tin plate in the order indicated in the diagram. Place the Bunsen flame under the edge of the plate farthest from the phosphorus. Watch for results.

Observations: What happened? Which substance began to burn first? How did it burn? Which burned last? Can you explain this?

[1] Phosphorus, because of its highly combustible nature, is a very dangerous substance to handle. Always keep it under water in a bottle and when using it cut off very small pieces at one time. Do not allow the fingers to touch it at any time.

Conclusion: Do different substances have different kindling temperatures or ignition points? Give your proofs.

Practical Application: Why is it well to keep phosphorus under water? Explain. What other method might be used to keep it from burning? Why are different materials used in building a fire? In what order are these materials placed in the stove or furnace? Study the structure of a match (Key Picture 8) and apply the knowledge you gained in this demonstration in explaining how and why a match is made the way it is.

94. Oxygen and Oxidation. — No burning can take place without oxygen and certain substances will burn better than others. This burning we call *oxidation.* If it is rapid enough to produce light, we call it rapid oxidation or *combustion.* We cannot see oxygen. We cannot feel it or smell it. We cannot even taste it. We may then call oxygen a tasteless, odorless, invisible gas. Such facts about oxygen we learn by the use of our senses and so we call these facts *physical properties.* Give two physical properties of nitrogen; two of air; two of carbon dioxide.

But oxygen can do things. It chemically unites with substances in wood, paper, etc., producing heat, light, water, carbon dioxide, etc. The things that oxygen can do are called its *chemical properties.* Does nitrogen have any chemical properties? Does carbon dioxide?

Thus we see that certain phenomena always accompany the process of oxidation. These may be summarized as follows:

(1) Oxidation is the chemical union of oxygen with other substances.

(2) Heat is always produced in the process of oxidation.

(3) Burning or combustion is rapid oxidation.

(4) New substances called *oxides* are always produced by the process of oxidation. (See Key Picture 5.)

95. Air, Fire, and Work. — All work done by air because of its weight, its pressure upon surfaces (owing to its being compressed), or its motion is purely *mechanical.* We are now concerned with the ways air is used or made to do work

because of its *chemical* composition and action. Your early demonstration with the coffee pot showed you that air and illuminating gas can do work. Gasoline and air also can do work in driving an automobile along the road. This work may be useful or it may be destructive.

U. S. Forest Service.

FIGURE 47.—FIRE IN THE ARAPAHOE NATIONAL PARK.

This fire burned 2500 acres of timber in 3½ hours and came close to 3 carloads of gunpowder. Give some causes of such fires. Give some ways of preventing them.

We cannot imagine what our lives would be without fire. Yet we read every day of the enormous losses caused by its destructive power. A few years ago someone carelessly left a fire burning in the Minnesota forest. The result was the loss of 600 human lives, the destruction of two towns, and the burning over of millions of acres of valuable timber.

Consider the great Chicago fire caused by the overturning of a lamp. Finally, try to think of the awful disaster in the

destruction of thousands of homes by fire during the World War. In every case, air, fuel, and fire did the work.

96. Oxidation Changes Matter but Does not Destroy It. — You now know that every change is an *effect* because it had a *cause*. This means that all changes in the world are controlled by *natural laws*.

But these changes are not all alike. A farmer plows his fields or chops down trees for firewood. Water freezes into ice. Water is heated and changes to steam. Wood or steel or stone is sawed into pieces. In every case the *form* and *shape* of the substance are changed but no *new* substances are produced nor has anything been destroyed. Such changes, as you now know, are called *physical changes* (Key Picture 5). Define such a change.

Again, you shovel coal into a furnace and it is consumed, — burned. Ashes appear in the ash pit and you get heat from the burning coal. Soil is changed by the sun through the help of rain and air into potatoes and wheat and apples. A building burns down and property is destroyed. The beams and floors of the house are broken up by the process of oxidation, producing new substances such as carbon dioxide, smoke, ashes, and water. A *chemical change* has taken place because the *nature* of the substances burned has been changed as well as their form and shape (Key Picture 5). However, the simple elements (oxygen, hydrogen, carbon, etc.) of the original substances have not been changed; they have merely entered into new combinations, forming new substances.

2. Oxidation and Its Control in the Home

97. Oxidation in the Home. — How can oxidation be used to advantage in the home? Under what conditions would you want to raise any substance to its ignition point? What would you want to produce in the process? Of what benefit would this process be to you? Think about these questions and then explain how the process is actually started in the home.

98. Matches. — Men lived for ages without matches. All fires were started either by rubbing two pieces of wood together until the point of ignition was reached or by producing a spark with flint and steel from which a piece of tinder could be set on fire. In the seventeenth century someone discovered that sulphur can be used to help start fires because it starts to burn at a much lower temperature than wood. A hot nail will set it sputtering. When burning, it will easily set wood afire. But it was as late as 1823 before the first " parlor match " was invented. To-day the consumption of matches is 700,000,000 every 24 hours in the United States. Phosphorus is used in all modern matches because its kindling point is even lower than that of sulphur. Very slight friction will set yellow phosphorus afire. The present-day "strike-anywhere" match is a black-tipped match and contains phosphorus trisulphide (trī-sŭl'fīd), a harmless form, instead of the very poisonous yellow form.

Make a careful study of the diagram of the match (Key Picture 8) and answer all questions upon it.

1. Observe and report upon 10 physical and 10 chemical changes which take place about you during a period of two days.
2. Determine the nature and use of products of some physical and chemical changes taking place about you.

99. Building Fires. — What materials are necessary to build a fire in your kitchen stove? Make a list of them as if you were about to work an experiment for yourself. Give a reason for the use of each thing you would use. Would you use paper? Can you see any need for this? Suppose you were to build a fire with shavings in the bottom of a pan. Try it and see what happens. Can you account for the result?

Now try to build a fire in your kitchen stove or in your furnace. What substance will you put in first? Explain. Why not put the coal in first? Do paper, wood, and coal all kindle at the same temperature? Can you see why this is so? How would you arrange the damper in the pipe? How would you set the draft in

the front of the stove? What should one always avoid in building a fire?

100. Smoke. — Smoke is unburned carbon and when it accumulates in a chimney, it is called *soot*. The burning of hard coal produces a minimum of smoke. The soft coal commonly used by railroads, steamships, and steel mills is very easily burned, but also very incompletely burned (Fig. 48).

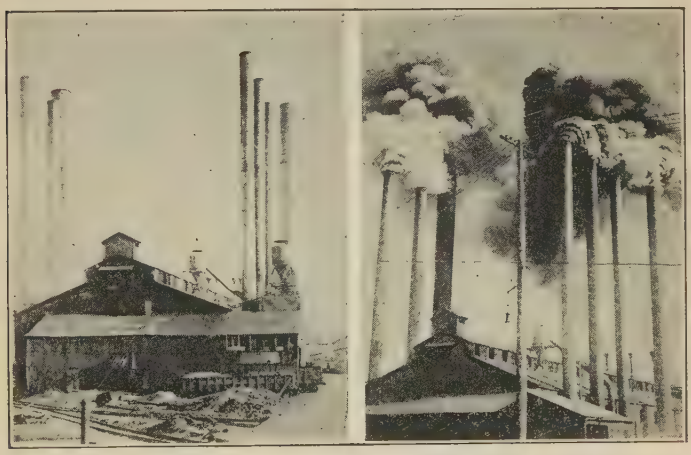


FIGURE 48. — THE SMOKE NUISANCE.

Two types of combustion. One is a nuisance. What causes this smoke? How can it be prevented? Why should it be prevented?

In great manufacturing centers it is a great problem to keep anything clean. Explain. This condition is known as the *smoke nuisance*. In many states laws have been passed requiring a checking of this evil and in many places manufacturers have installed smoke screens which take out the smoke as it passes up the chimney and use its contents as by-products, which are in reality very valuable. How would you prevent the formation of much smoke in your furnace? Explain.

101. Importance of Fire in the Home. — Imagine what would happen if all the fires in the whole country should

suddenly go out and could not be rebuilt. All work of importance would soon stop. Why? Our food would be raw meat, berries, leaves, and roots. In time we should have few utensils such as knives, clocks, stoves, shovels, and other implements of work. Explain this.

Demonstration 12: *Problem: Can oxidation occur without a flame?*

Materials: Fine iron filings; a test tube; a glass tumbler; and an iron ring stand.

Method: Moisten the inside of the test tube. Pour in some of the iron filings and invert it in the glass tumbler containing some water. Fasten tube in position with iron ring stand. Mark the level of the water on the inside of the test tube. Set aside for 24 hours. (Fig. 49.)

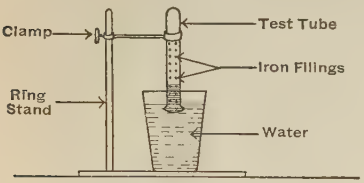


FIGURE 49. — DEMONSTRATION 12.

What caused the water to rise in the test tube? Does this resemble any other experiment you have already done? Explain.

Observations: Why did the water not rise farther in the test tube? What do you note about the color of the iron filings after 24 hours? What has really happened to them? Note the height of the water in the test tube. Can you account for its rise? What has probably been used up from the air? Where has it gone? What do you suppose has actually taken place in the iron filings? Do you see a flame? Do you feel heat? Has the process been fast or slow?

Conclusions: What is your conclusion? Give your proofs.

102. Slow Oxidation in the Home. — Slow oxidation is silent and is not easily noticed, but it meets us on every hand and causes a large part of the yearly repair and upkeep bill of every home. Why is this so? Well, as you have learned, iron is easily oxidized when exposed to the *air* and *moisture*. Even bright copper, in time, loses its lustre. The changed materials are *oxides* of the substance oxidized. All oxides consist of oxygen and some substance with which the oxygen unites. Is carbon dioxide an oxide? Water? Explain. To prevent this slow oxidation which in iron and steel we call *rust-*

ing, we must cover the surface of the metal with something which will keep out the air and moisture. (Key Picture 5.)

In spite of such precautions, however, recent investigation shows that the loss from rust in this country every year is above $2,000,000,000 (two billion dollars).

A paint advertisement commonly seen says: "Save the surface and you save all." What does this mean? Explain. When wood rots, it means that slow oxidation has done the work. The painting of the woodwork of a house, shingles, clapboards, or any other wooden surface exposed to air and moisture, is the only means known of preserving them from destruction.

1. Study and report upon as many examples of slow oxidation as you can observe in one week.
2. Make a study of the best methods in use to-day to stop slow oxidation and report upon them.
3. Name some utensils that will not easily oxidize because of the kind of materials of which they are made.

103. Dangers of Slow Oxidation in the Home. — The oxidation of the oil in paints hardens them. In this process the temperature of the paint is slightly raised. Explain. Now it often happens that oil-soaked woolen or cotton rags are left about the house in out-of-the-way places. If piled in heaps or rolled up, the oil will slowly oxidize, the temperature may be raised to the kindling point, and rapid oxidation (with its flame) will begin. Disaster to the home often follows. Many destructive fires have started in just this way. It would be well for you to look about your home to discover if any such menace can be found.

3. Do Living Things Burn?

(Key) Demonstration 13: ***Problem: Does oxidation occur in living things?***

Materials: Limewater; a small battery jar; a live fish (silver fish or sun fish); a test tube; one foot of glass tubing; a small handful of germinating pea seeds; a wide-mouthed bottle; and a small vial of limewater. (Fig. 50.)

Method: *A.* Pour enough limewater into the battery jar to cover the fish. Place the fish in this limewater for a few moments and watch the limewater.

B. Put the seeds and the uncorked vial of limewater into the wide-mouthed bottle. Cork the bottle. After 24 hours note the condition of the limewater.

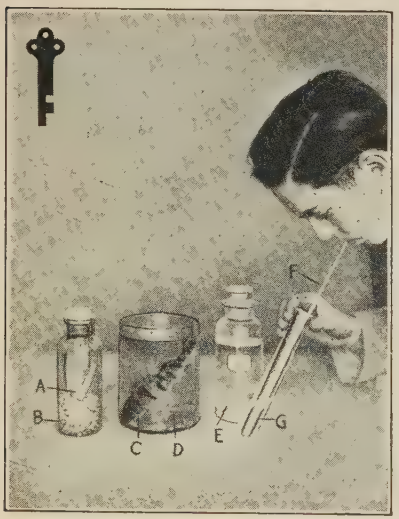


FIGURE 50. — (KEY) DEMONSTRATION 13.

A, vial of limewater; **B**, germinating pea seeds; **C**, fish; **D**, **E**, limewater; **F**, glass tube; **G**, test tube with limewater.

Can you see why the limewater was placed in the bottle with the germinating pea seeds? Why was this bottle closed? How are the seeds, the fish, and the boy all alike?

C. Blow the breath through the glass tube into some limewater in the test tube.

Observations: What was the color of the limewater in each case? What does this indicate? How is carbon dioxide produced? Of what is it the oxide? In what other experiment did you produce this gas? What process will produce it in connection with carbon?

Conclusions: What process is going on in plants, fishes, and human beings? How do you know? What kind of oxidation is it? Explain. Can you conclude that all living things carry on this process? Explain. What, then, does every living thing need? Can you now account for the heat of the body? What substance must burn in the body to produce CO_2[1] and heat? Explain. Did you ever breathe against the surface of a cold mirror or window pane? What did you notice? What other substance is given off in the human breath? What process probably produced it? What substance must have burned to produce it? Answer these questions in your Science Discovery Book.

[1] CO_2 is the chemical symbol for carbon dioxide, each molecule of which is composed of one part of carbon and two parts of oxygen.

104. Exercise and Oxidation. — Does exercise increase oxidation? Take a count of your pulse for one minute. Place a clinical thermometer under your tongue for two minutes. Note the temperature. Now exercise hard for one minute. Take the pulse and temperature again. What do you note? Do you breathe faster? Why? What caused a higher pulse? Did the temperature rise? Explain.

4. How Do Living Things Breathe?

105. How You Get Air into Your Body. — You are now ready to find out how your apparatus for securing air actually works.

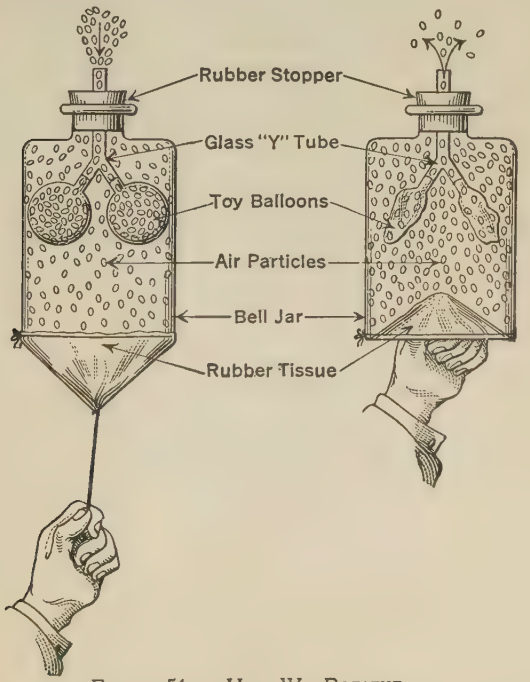


Figure 51. — How We Breathe.

Why does the air enter the balloons when the string is pulled down? Account for the difference in the appearance of the air particles in each jar. Why does the air come out of the jar?

Suggested Experiment. — Secure a bell jar open at the top, a one-holed rubber stopper, a glass " Y " tube, two toy balloons, some rubber tissue, a stout cord, and a small marble. Arrange the materials as in Figure 51. Tie the marble in the center of the rubber tissue. Pull down on the string. Relax upon it. Repeat.

1. What happens to the balloons? 2. When do they fill? 3. Why do they empty? 4. What can you say of the air capacity of the bell jar when the membrane is pulled down? when the membrane is allowed to rise? 5. Does air pressure have anything to do with the action here observed? 6. What is formed in the jar when the diaphragm (dī′ȧ-frăm) or membrane is pulled down?

Now study a diagram of the breathing apparatus in the human body and find the parts of it which correspond to the parts of the apparatus in this experiment. Then answer the following questions:

7. What pulls the diaphragm down? 8. What effect does this have on the chest cavity? 9. Why does air enter the lungs? 10. Do you " suck " in air when you inhale? 11. What makes the lungs expand? 12. What makes the lungs collapse? 13. What causes the ribs to rise and fall?

Record in your Science Discovery Book what happened in this experiment. 1. How does a person breathe? 2. What is the advantage of a large chest or lung capacity? 3. Why is it well to stand up straight? 4. What is the disadvantage of wearing tight belts or other tight clothing about the body trunk?

Special Problems:

1. *To devise a method of increasing your lung capacity.*

Suggestions: (*a*) Determine your present lung capacity by: (1) measuring the circumference of your chest below the arms after you have taken into your lungs as much air as you possibly can; (2) measuring again after you have driven out all the air. The difference between the two measurements is your chest capacity (expansion).

(*b*) Select some form of exercise suggested by your teacher to increase your chest expansion and begin to follow this daily.

(*c*) At the end of the second week make measurements again. Do so for several weeks. Make a chart or graph showing your progress.

2. *To make a spirometer* (spī-rŏm′ē-tēr) *or other simple apparatus to test your lung capacity.*

Suggestions: (*a*) Secure a large water bottle, fill with water and invert in a shallow dish of water. Why does the water not all run out?

(*b*) Using your own methods work out a plan by which you can use this bottle of water to test the comparative lung capacity of yourself and two companions. Determine the average.

(*c*) Work out a plan by which you can actually measure the amount of air you can hold and exhale from the lungs.

106. Air and Living Things. — You may conclude, then, that living things need air. Animals die without it. You have sometimes felt the need of air in a close, stuffy room

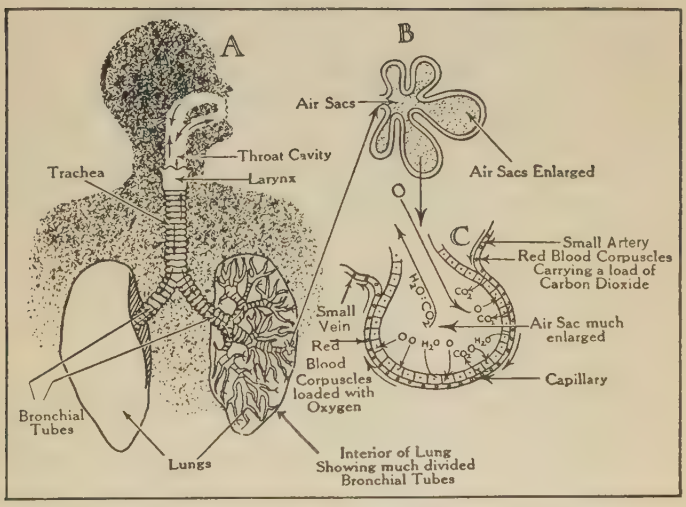


FIGURE 52. — OUR BREATHING ORGANS.

A, the organs in their proper position in the body. Name each part and give its functions. **B**, one group of air sacs much enlarged. **C**, one air sac still further enlarged. Note carefully each part and its relations to the others. Explain fully what goes on here.

and have sought relief by moving out of the room or opening the windows. People who drown or those overcome with smoke in a burning building lack air. People who faint need plenty of air to resuscitate (rē-sŭs′ĭ-tāt) them. What is there in the air so necessary to human life?

107. Breathing. — When you take in a deep breath, the air (oxygen) enters the air sacs of the lungs (Fig. 52).

All living things which can inhale and exhale (insect, frog, bird, and man) breathe. Breathing is the taking in of air (oxygen) and the giving off of carbon dioxide. The actual exchange of these gases through the walls of the cells (Section 110) is called *respiration.* The oxygen is carried by the blood stream through the body. It unites with certain body materials to form carbon dioxide, and in so doing supplies heat energy so that you can move about and do work. This process, oxidation, is a part of respiration.

108. Rate of Breathing. — The normal rate of breathing of human beings at your age is about 18 times each minute. For different animals with lungs, the rate differs. Some animals seem scarcely to breathe at all. Name one. Is it an active animal? Others, when hibernating, probably do stop active breathing. Birds breathe with great rapidity. They are also extremely active. We see, then, that there is a close relation between the rate of breathing and the natural activity of the animal. It follows, then, that increased activity by any animal means an increased rate of breathing. Explain this statement. What is one value of exercise?

109. Oxidation and Living Substances. — Light and heat are given off in the rapid oxidation of wood. Oxidation goes on in rusting iron, though we neither see flame nor feel heat. In the body we feel heat but see no flame. Placing the hand on the top of the head will prove that heat is given off. Here we have wet oxidation because the protoplasm (Fig. 54, A and B) is actually used up. (Key Picture 5.)

110. Cells, the Units of Structure. — In 1838 and 1839, Schleiden and Schwann, two German scientists, discovered by the use of an improved microscope that all living things are composed of minute, irregularly shaped bodies called *cells* (Fig. 53a). Each cell consists of a tiny mass of jelly-like, colorless matter which is called *protoplasm* (Fig. 53a). The protoplasm has a covering of living material known as the cell *wall.* In plants, the cell wall contains a substance called *cellulose,* which resembles cotton fibers in structure. In the

cell there is a *nucleus* (nū′klê-ŭs) (Fig. 53a), meaning a kernel. This nucleus seems to regulate all the life processes of the cell. It is in the cell that oxidation takes place (Key Picture 5).

111. Tissues and Organs.—Some plants and animals, it is true, consist of but one cell, but the vast majority of living things consist of millions of cells. All many-celled plants and

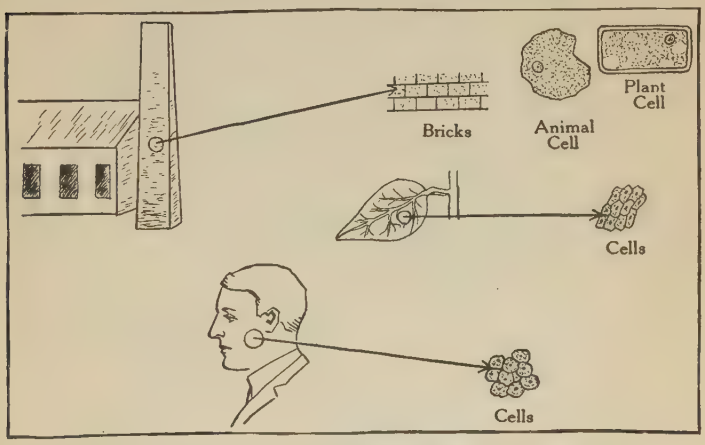


FIGURE 53A.—CELLS: THE BUILDING BLOCKS OF LIVING THINGS.
Wherein are the three structures here illustrated similar? How do they differ? Explain. Name the parts of each type of cell.

animals have their cells grouped into *tissues* (tĭsh′ūz),—masses of cells alike in size and shape and all doing the same kind of work (Fig. 53b). Again, tissues are grouped together to form *organs* (Fig. 53b), such as the leaf or the heart. Each organ performs some important work in the body of the plant or animal. The whole plant or animal is called an *organism*. An organism is a living thing and consists in the case of the human organism of about three billion cells. How does oxygen get to every one of these cells? Study the figures, page 136, and discuss them in class. (Key Picture 5.)

Laboratory Exercise. — Examine under the low power of a microscope a small portion of the leaf of the *Elodea*,[1] a water plant. Note the brick-like cells. You may notice the protoplasm moving about in the cells. What does this prove? Next peel off a very thin piece of the surface of one of the thin inner scales of an onion bulb. Examine in the same way. Note the cell walls and the nuclei (plural for nucleus). Finally, remove a thin portion peeled from the under side of a tulip or onion leaf. Examine as before and note the tiny openings called *stomata* (mouths — singular, *stoma*).

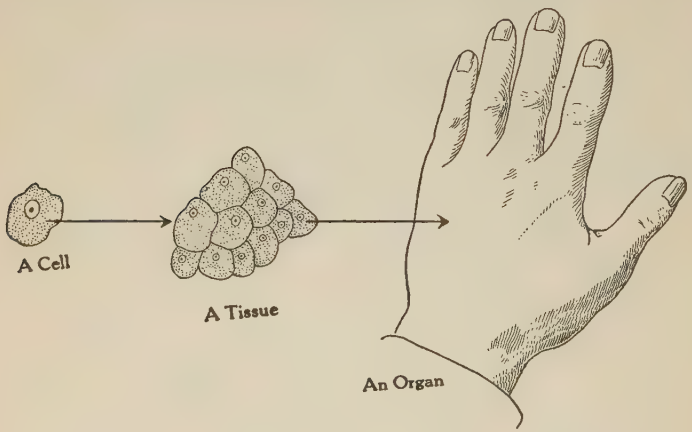


FIGURE 53B. — HOW ORGANS ARE BUILT UP FROM CELLS.
Explain this picture. What will a group of organs make?

112. Oxidation of the Cells. — Since it is the protoplasm that burns, you can see, then, that the oxygen must be brought to the cells by some common carrier and the wastes produced by the oxidation process must be taken by this same carrier to places where they can be eliminated from the body. This common carrier is the *blood*, pumped about the body in *blood vessels* by the action of the *heart* (Plate V). The *red corpuscles* (kôr'pŭs-'lz) in this blood carry the oxygen to the cells and pick up the carbon dioxide and bring

[1] The Elodea is a common aquatic plant easily procured from bird stores and is commonly used in aquaria. A substitute for Elodea would be the stamen hairs of *Tradescantia*.

it back to the lungs. Where do the corpuscles pick up the oxygen? These tiny bodies may be compared to boats carrying cargoes. What is this cargo? Does it change? Where is the change made?

113. How Plants and Animals "Breathe." — Most people think that a plant "breathes" (Section 107) carbon dioxide which animals give off. Green plants use this gas, it is certain, but they do not breathe it. Plants must have oxygen as well as other living things, but they get it in a far different way than the fish or the dog or man does. Your observation of the tulip leaf epidermis showed you enormous numbers of tiny holes called *stomata* (stō′mȧ-tȧ). As many as 240,000 have been counted in a square inch of the under side of an apple leaf. You may now get a partial clue of how the plant is adapted for getting oxygen. Passageways must run from these holes to every part of the plant. Explain. Study carefully the diagram of the leaf, Key Picture 16, and explain the use of its parts. Then explain how a plant "breathes." Insects breathe through *spiracles* (tiny air-holes) which occur along either side of the abdomen. From each spiracle a *trachea* (tiny air-tube) carries the air to the cells. A careful observation of the fish will show that it does not possess lungs. Is there any air in the water? How is the fish adapted to get air in the water? Study Figure 54 and learn how the fish and plant are adapted to get oxygen.

(Key) Demonstration 14: ***Problem: Does water contain air (oxygen)?***

Materials: A 1000 c.c. Florence flask; an iron tripod; a square of wire gauze; a Bunsen burner; some water; two small battery jars, one containing water and a goldfish; and a glass plate large enough to cover one of the jars. (Fig. 55.)

Method: Place the flask full of water over the Bunsen flame. Note if any action takes place. Explain. As soon as the water is brought to a boil, cool it by holding the side of the flask under running water. After it is partly cooled pour the water into the empty battery jar and cover with the glass plate. Set aside until the water is fully cooled. Now take the goldfish from the jar where

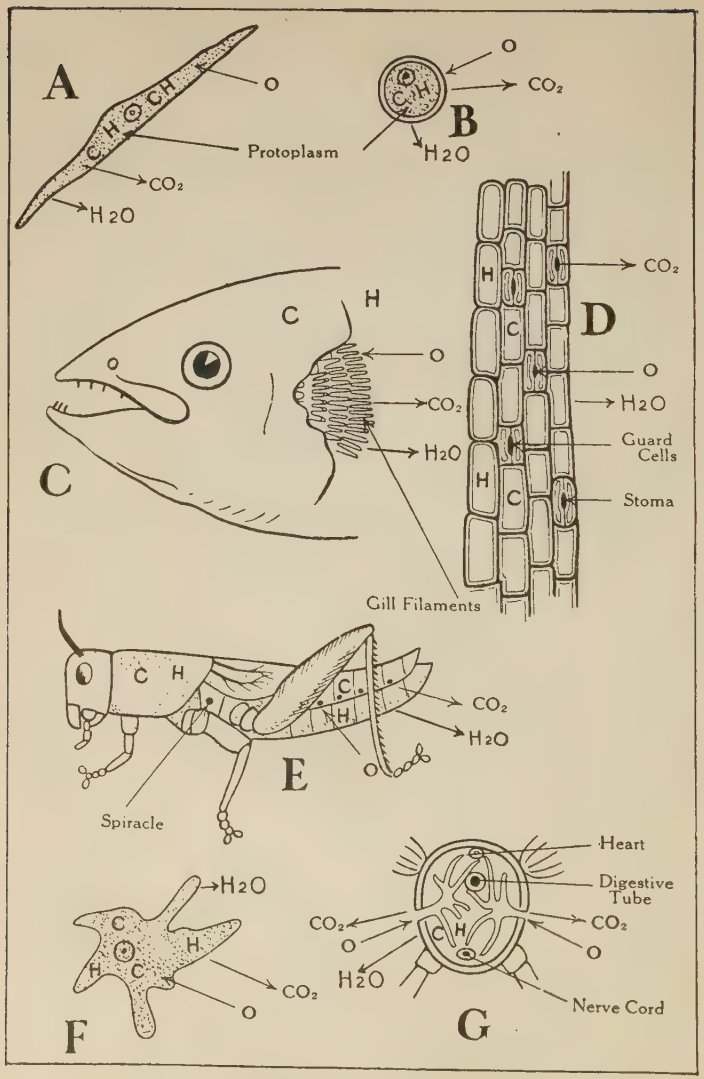


FIGURE 54. — HOW LIVING THINGS "BREATHE."

A, muscle cell; **B**, simple plant cell; **C**, fish; **D**, under-surface cells of a green leaf; **E**, grasshopper; **F**, amœba, a one-celled animal; **G**, cross section of grasshopper.

it is swimming about and place it gently in the jar of cooled water. Note the actions of the fish and *immediately* replace it in the first jar.

Observations: What effect did the heat have upon the water in the flask? What kind of gas was in the bubbles? How do you know? Account for the action of the fish when placed in the cooled water. Account for its action when returned to the first jar. What did the first jar contain that the second jar lacked?

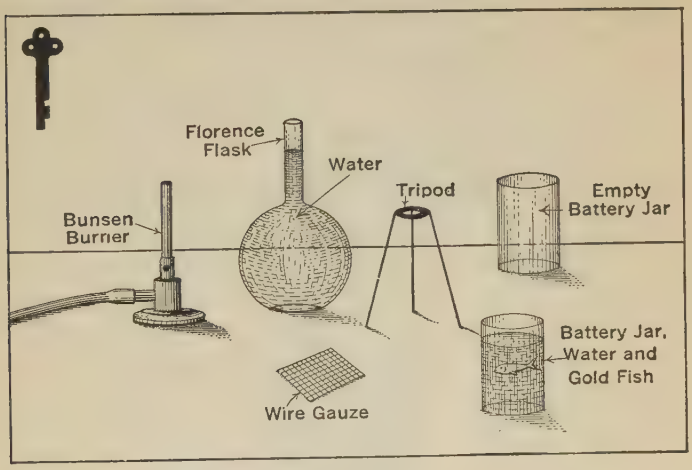


FIGURE 55. — (KEY) DEMONSTRATION 14.

Explain fully the use of each part of apparatus in this experiment. Why does the water in an aquarium have to be changed often when no plants are used?

Conclusion: Does water contain oxygen? Give your reasons. Write this demonstration out in full in your Science Discovery Book.

A fish, then, gets its oxygen by the use of an apparatus for taking free oxygen from the water. This consists of four rows of *gill filaments* on each side of the head and covered with a tough flap, the *operculum* (ō-pûr'kū-lŭm). Study Figure 54. Then describe the process of respiration in a fish.

114. Deep Breathing. — The normal capacity of our lungs is about 330 cubic inches of air. Many persons have a capacity below this and few above it. Setting up exercises or a brisk walk will generally make one feel more alert. Can

you offer an explanation of this? Therefore, if you can bring your lung capacity up to normal, you can do better work. Added lung capacity means an added amount of *complemental, reserve,* and *residual air* (Fig. 56). This means a constant and even supply of air in the lungs under all circumstances, — in diving, in running, in cases where the breathing must be suspended for the moment. What do we

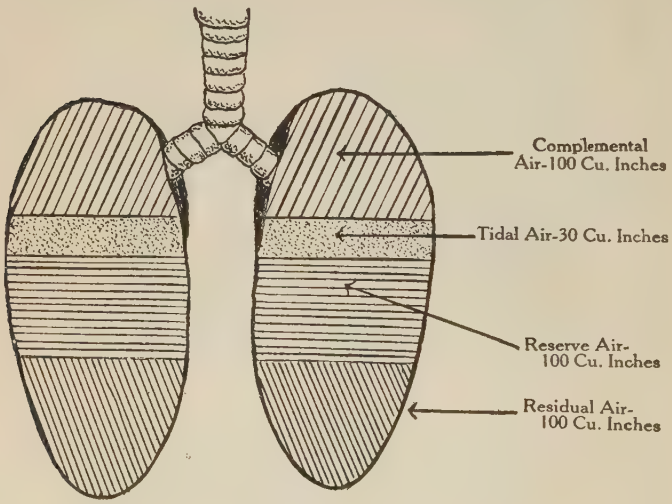


FIGURE 56. — YOUR LUNG CAPACITY.

The shadings of the drawing represent volumes of air, not distinct layers. Tidal air represents the volume changed in ordinary breathing; complemental, the volume changed in light exercise (walking); reserve, the volume changed in brisk exercise (hand-ball); and residual, the volume changed in violent exercise (running a mile).

mean when we say that a person is short winded? long winded? What does getting your "second wind" mean? The extra supply of oxygen in the lungs is fatal to minute organisms called *bacteria.*

115. Methods of Breathing. — *Deep* breathing is necessary to insure health and efficiency and should be done at regular intervals each day. Other exercises may be followed

with profit. Such exercises should be continued for at least three minutes each time and, if possible, before or near an open window. To discover a common obstacle to deep breathing place your feet up on the rungs of a chair while sitting in another chair. Then fold your arms tightly across your chest and bend forward. Try to take a deep breath. What is the result? What does this little experiment teach you?

Care should be taken at all times that the breathing be done through the nose and not through the mouth. Check yourself on this. If you have difficulty in breathing through the nose or if you are a mouth breather, it may be that spongy growths, called *adenoids* (ăd′ĕ-noidz) (see Fig. 287), are forming or have formed up behind the soft palate at the beginning of the passageway to the nose. Again, mouth breathing may be due to a cold or a catarrhal (kȧ-tär′ăl) condition of the mouth and throat, clogging the nose passageways and many times interfering with the hearing. This means (1) a marked reduction in the flow of blood to the head, (2) a loss of nervous energy, (3) inability to concentrate the attention upon the work in hand, (4) a dry throat, (5) frequent colds, (6) earache, and (7) the inability to pronounce words distinctly. With constantly parted lips one is more subject to bacterial diseases of the throat, nose, and even the lungs. Explain.

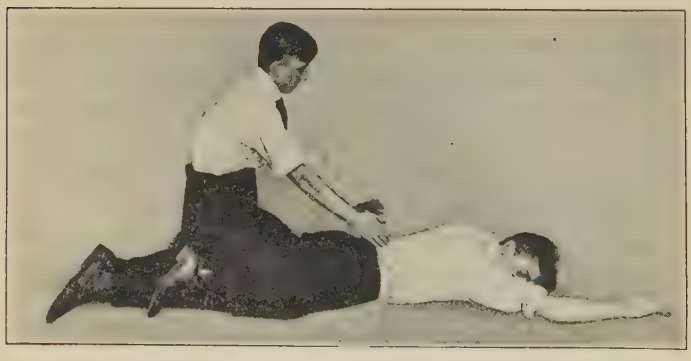
Nose breathers, on the other hand, avoid all these ills because (1) the nose hairs strain out the dust, (2) the mucus catches the dust, and (3) the air is warmed by the long nose passages. Nose breathing insures plenty of oxygen for the lungs provided the nose passages are clear.

Demonstration 15: *Problem: What is meant by artificial respiration and how is it administered?*

Materials: A member of your class and a table.

Method: Place your patient on his stomach. Place a rolled-up coat or pillow under his stomach. What is the use of this? Stand beside the body and grasping both sides of it in the region of the

lower ribs with the open hands (thumbs on top and fingers underneath) press firmly down for a moment and then lift the body up a few inches. What will both of these movements do for the body?



Note position of both patient and rescuer. What is the advantage of each position?

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What is the effect of the down thrust? What is the effect of releasing the pressure? Try this for practice on a companion.

FIGURE 57. — DEMONSTRATION 15. THE SCHAEFER METHOD OF ARTIFICIAL RESPIRATION.

Observations: Write out in full your observations in this demonstration. Give the advantages and disadvantages of this method.

Conclusion: What is the meaning of artificial respiration? How is it administered?

Practical Application: Practice this method (Schaefer) on each other. The results may be most practical; for you may be called upon to save a life and you may be successful in doing it because of your knowledge gained in this demonstration.

116. Artificial Breathing. — If a gas jet has been blown out, allowing gas to escape into a room in large quantities, or if the deadly carbon monoxide has accumulated from improper attention to a furnace, or again, if thick smoke from an unexpected fire cuts off a way of escape, the proper supply of oxygen is denied the body exposed to such dangers.

Death frequently follows unless heroic measures are used. If conscious and able to move, the inmates should run out of the house at once. In case of thick smoke one should crawl along the floor. Why? In case of asphyxiation (ăs-fĭk′sĭ-ā′shŭn) by gas or smoke the rescuing must be done by someone who knows what to do and how to do it. After the rescue the first thing to do is to send for a physician. Meanwhile, loosen the patient's clothing at the throat and chest and see to it that nothing prevents the free entrance of air to the mouth. Place the patient on his stomach with a pillow or coat rolled up beneath him and begin artificial respiration by the Schaefer method. (Study Figure 57 and answer all questions upon it.)

5. Changing the Air in Your Home

117. The Meaning of Ventilation. — A person should have all the pure air possible, indoors or out. So we *ventilate* our homes. What does this mean? Why should one ventilate the home at all times? In order to know something about this process it will be necessary for you to build a model room.

Suggested Experiment. — Secure or make a box 1′ long, 8″ wide, and 6″ high. Cover the top with a pane of glass 12″ by 8″. Stand the box on its side as shown in Figure 58, bore one-inch holes as indicated, and fit these holes with corks. Place three short candles, as shown in the diagram, and a small dish of limewater in the box. Now light all the candles and close all the openings in the little

room. Note the time that the candles are lighted and watch for results. What happens to the candles? to the limewater? Explain this. What time elapsed? Now light the candles again and leave all the holes open. Time the candles as before. What do you now note? Explain this also. You have just now ventilated the room. What is ventilation?

(Key) Demonstration 16: ***Problem: What is a good method of ventilating a room?***

Materials: The same as above, except the limewater.

Method: Set up the apparatus as in the *Suggested Experiment* above, omitting the limewater. Keep in mind that the box rep-

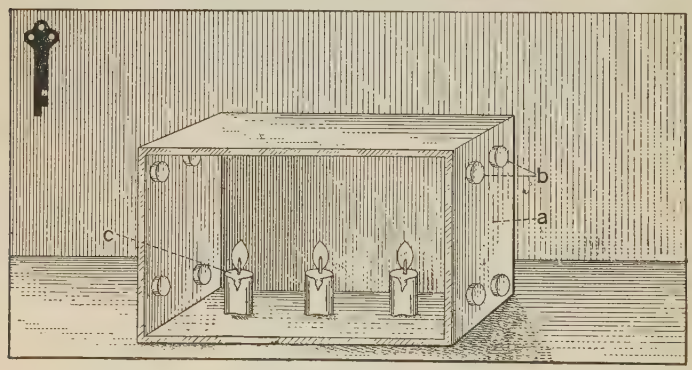

FIGURE 58. — (KEY) DEMONSTRATION 16.
a, box; b, corks; c, candles. How does this box resemble a room?

resents a room and that the holes are windows. Close the holes and light the candles. Just before the candles are about to go out, take out the upper row of corks in each end of the box. Observe the candles for several minutes. Now put in corks and remove the lower row of corks in each end. Observe as before. Finally, replace all corks and remove both upper and lower ones from *one end* of the box alone. Observe as before.

Observations: Which candles were most affected in the first test? the second test? the third? Explain. In which test did the candles burn the longest? Explain. In which test were distinct currents of air set up? Explain. Make a sketch of the model room and show by arrows what must have been the paths of these air currents which kept all the candles burning for an indefinite time.

Conclusion: What is the best method of ventilating a room? Give your proofs. How could you arrange the window in your own

sleeping room to set up and maintain currents of air as indicated in this experiment? Try it in your own room and record the results.

Special Problems.

1. Observe and make a report upon the structures used by a fish, a frog, and an insect in breathing and how each structure works.
2. Examine living cells under the microscope. Learn and report upon their similarities and differences.
3. Become an expert in the administration of artificial respiration.
4. Study and report upon the apparatus used by divers.
5. Organize a First Aid Club among your associates.
6. Study and report upon the likenesses and differences between plant and animal cells.

(*a*) Secure a thin portion of the surface of a tulip leaf; a small portion of the thin tissue of an onion, and a few cells from the lining of the mouth.[1] Place each on a separate slide, touch a drop of water to each, cover with cover glass and place on stage of microscope. Examine each under the low power. How are they all alike? How all different? What is the essential structure in each cell?

118. Free Air. — This important substance is in great abundance all about us. In spite of this fact, many people, little realizing that it is more precious to them than water or food or anything else, shut it out of their homes as though it were poisonous. Two or more hours spent in the open air each day, regardless of the weather, is an almost certain guarantee against colds, sore throats, bronchitis (brŏŋ-kī′tĭs), and kindred diseases of the respiratory system.

119. Importance of Ventilation.[2] — It is only by supplying oneself with at least 600 cubic feet of air an hour that one's

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[1] The mouth cells can easily be secured by gently moving the edge of a sterilized knife blade across the inner surface of the cheek. The material which collects on the blade should then be placed on the slide.

[2] The word "ventus" in Latin means "wind." Ventilation, then, is the proper circulation of air about a room. In this way, if the windows are open, a maximum amount of oxygen and a minimum amount of carbon dioxide will be found in the room at all times.

body can be kept at its proper condition. This means that the circulation of the air is absolutely essential to good health and good work.

120. Pure and Impure Air. — Pure air consists of the following gases in the following proportions:

Nitrogen 78%+ by volume.
Oxygen 21% by volume.
Carbon dioxide 0.03% by volume (variable).
Water vapor .03 to 3% by volume (variable).
Argon 1% by volume.

Such air is made impure by the addition of dust, bacteria, other foreign bodies, and more carbon dioxide.

121. Stagnant and Humid Air. — A far worse danger than impure air is air full of moisture and at rest. Exercise is beneficial because a fresh supply of *moving* air is constantly brought in contact with a *moving* body. But in a room where movement is not rapid or continued and ventilation is not insisted upon, the air settles down and becomes *stagnant.* A feeling of discomfort, listlessness, and suffocation follows.

The humidity of such air also causes one to feel very warm, and he will perspire while sitting still because the moisture cannot evaporate and the body heat is prevented from escaping.

122. Overheated Rooms. — The great defect of the average apartment house and home is overheated rooms, especially if heated with steam. Profuse perspiration follows, with discomfort and real danger when one steps outdoors from a room so heated. Stepping out-of-doors, especially in cold weather, with the skin moist with perspiration and the pores open, often results in a severe cold.

Any temperature much above 70° F. is harmful. The proper temperature is from 65° F. to 68° F. A factory should have the lowest temperature, the church and school the next higher, and the home the highest. Explain. Check the temperature of your home daily for a week and seek means of correcting it if it is wrong. Will this correction have any effect on the coal bill?

123. Other Factors. — It has been found that microscopic particles of lung and throat tissue, called *effluvia* (ĕ-flo͞o′vĭ-ȧ), are thrown off with each breath we exhale. These particles soon decompose and produce a fetid odor so noticeable in ill-ventilated rooms. Besides, many obnoxious (ŏb-nŏk′shŭs) odors come from unclean bodies and unclean clothes. Again, carbon monoxide or coal gas is often present in rooms, though it may not be enough to be noticeable. Finally, the air may be full of dust particles laden with bacteria, many of which may be harmful. The result may be irritated air passages which make easy the contracting of colds, diphtheria, croup, mumps, pneumonia, and tuberculosis.

124. Proper Air Movements. — Recent experiments upon students show that persons cannot stay in an air-tight compartment containing still air without at once becoming uncomfortable. In the tests the temperature of the compartment was raised to 85° F., the air so filled with moisture that it formed as vapor on the inside of the glass walls and the carbon dioxide content of the room was raised to 4%. At this moment electric fans in the compartment were set going and the students felt immediately relieved. Proper movement of the air, then, by means of ventilation insures the proper condition of the air in any home.

125. How to Ventilate Your Home Properly. — The simplest and surest method of ventilation is the opening of the windows and doors at times, even though a strong draft is set up. The draft is a sure indication that you are getting proper ventilation. There is some difference of opinion as to how the windows should be adjusted, but your experiment with the model room leaves no doubt that there should be two openings, one at some distance above the other on the *same side of the room.* The reason for the two openings is plainly seen. Study Figures 59a and 59b and give the reason.

126. Systems of Ventilation. — There are two acknowledged systems of ventilation: the *natural* and the *artificial.* Those mentioned so far in this chapter are natural and they

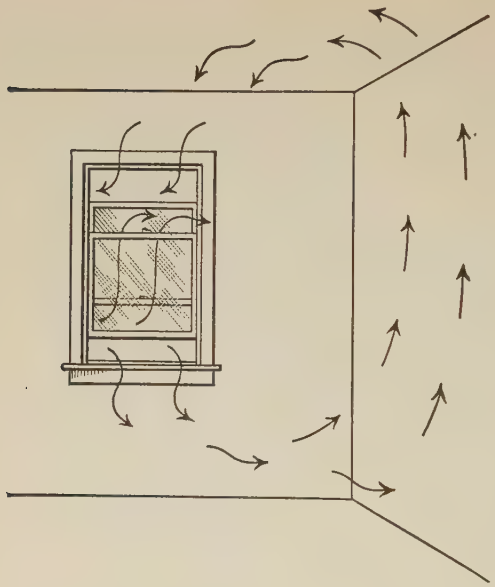


FIGURE 59A. — NATURAL METHOD OF VENTILATION.

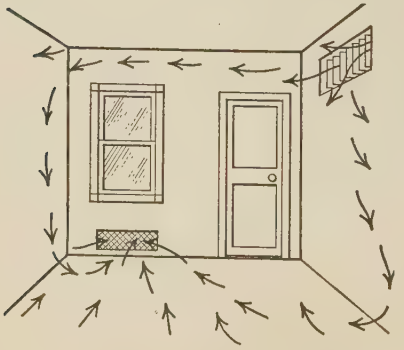


FIGURE 59B. — ARTIFICIAL METHOD OF VENTILATION.

Account for the direction of the arrows in these pictures.

are considered by many authorities the very best. The artificial system works automatically after its permanent adjustment. The air, containing the right amount of moisture, is warmed to the right temperature and sent into the room by fans. The stagnant air full of impurities is removed through a separate opening near the floor, while the air of the whole room is kept in constant motion.

In many of the schools of New York City artificial ventilation is in use, but a recent report of an investigating committee showed that there were 32% more absences due to respiratory diseases in the forced-draft (artificially ventilated) rooms than in the open-window ventilated rooms, where the air was kept at 68° F. It was also discovered that in the forced-draft rooms there were 98% more respiratory diseases recorded than in the open-window rooms. This comparison speaks for itself.

KEY WORDS

NOTE. — Do not forget what you are to do with the following key words. Also, remember what the " stars " mean!

adenoids *
argon
artificial respiration *
bacteria
blood *
blood vessel *
breathing *
carbon dioxide *
cells *
cellulose *
chemical property *
combustion *
complemental air *
diaphragm *
Elodea
gill filament *
heart *
humid air *
hydrogen
kindling (ignition) point *
Lavoisier *
manganese dioxide *
mercuric oxide *
nitrogen *
nucleus *
operculum *
organs *
oxidation *
oxides *
phosphorus
physical property *
potassium chlorate
Priestley *
protoplasm *
reserve air *
residual air *
resuscitate *
rusting *
Schleiden *
Schwann *
Schaefer method*
smoke *
soot *
soft palate *
spiracles *
stagnant air *
stomata *
tissue *
trachea
ventilation *
natural
artificial
wet oxidation *
" Y " tube

REVIEW OUTLINE

1. Fire: Method and importance of its discovery.
2. Air and Fire: Necessity of air to fire. Composition of air. Part used in burning. Products of burning and their properties.
3. Why a Fire Burns: Discoveries of Priestley and Lavoisier. Relation of oxidation and combustion. Physical and chemical properties of some substances which will burn. Results of oxidation.
4. Air, Fire, and Work: Work of fire. Burning does not destroy matter. Physical and chemical changes involved.
5. Oxidation in the Home: Matches; history; use. Building a fire. Importance and dangers of oxidation. Slow oxidation.
6. Oxidation in Living Things: Necessity of air to living things. Apparatus for breathing in living things. Method of breathing in the human body.
7. How Living Things Burn: Protoplasm the basis of animal and plant structure. The cell the unit of structure of all living things. Tissues and organs. Cell oxidation. How the simpler plants and animals "breathe." Artificial respiration.
8. Ventilation: Meaning and importance. Pure air; nature and importance. Necessity of and factors involved in proper ventilation. Modern systems. Open-window method the best.

THE SUMMARY

You have now noticed and used four summaries. Each is found at the end of a chapter. It is intended that each shall be a short, clear, and simple essay or story of the chapter, including all its essential points.

The summary will prove an excellent review for you. When you read it you read the whole chapter in a page or two. Therefore, every sentence contains a large number of thoughts and facts. Can you enlarge these sentences and tell the whole story hidden within them? If you can, you will know the great truths of the chapter.

You should be able to tell everything important about each of the italicized words and phrases. Here you have a key to the whole chapter. Use it to unlock the door to what you ought to know and remember about the chapter.

SUMMARY

It was not until the year 1774 that anyone knew that air had anything whatsoever to do with fire. By the work of *Lavoisier* and *Priestley* we know now that fire is impossible without *oxygen*, the part of the air which makes things burn. This gas, forming about one-fifth of the atmosphere, supports combustion and is kept in check by the large amount of *nitrogen* in the air. Nitrogen will not support combustion.

When substances such as wood, paper, and coal burn, they produce *heat*, *light*, a gas called *carbon dioxide*, and *water*. These common fuels all burn at different temperatures called their *ignition points;* this fact makes them valuable to us in building fires and dangerous to us if they are not properly protected from fires. These substances when burning emit *light* and much *heat* and thus illustrate *combustion* or rapid *oxidation*. They are fast changed in *form* and *composition*, but the substances of which they were composed are not destroyed.

Oxidation in the home releases heat which is used in the preparation of foods and the warming of the house. Such oxidation is generally begun by the use of matches. But with the burning of fuels in the home come dangers which must always be guarded against.

Slow oxidation is most commonly seen in the rusting of iron utensils such as an *iron kettle* or a *nail*. An *iron oxide* or *rust* is formed, but such formation may be prevented by the application of a coating of oil or paint, which keeps out the oxygen of the air. Dangers of fire from slow oxidation in the home must also be guarded against.

Living things also burn slowly, releasing *heat*, *carbon dioxide*, and *water*. Different living things have different types of apparatus for securing *oxygen* to carry on oxidation in order to *release heat energy for work*. The human body is supplied with the *lungs*, which get fresh air in and foul air out of the body. This air through oxidation releases heat in the body, and in so doing supplies energy for the various body activities. The human body is made up of *protoplasm*, *cells*, *tissues*, and *organs*. Oxidation goes on in each cell, which is a tiny engine in itself. A large and regular amount of air is supplied to the body by *deep breathing*. This supply of air must be *pure* and free from *dust* and *bacteria*. To aid in this work *ventilation* is necessary which should keep the air always at a certain *temperature*, *moist* and *in motion*. The most healthy form of ventilation is that produced by *open windows*, provided no strong drafts are formed, the room is properly heated, and the air kept moist.

Remember that:

1. Oxygen is necessary to combustion.
2. Burning a substance does not destroy its elements.
3. Oxidation can take place without fire.
4. Living things burn, releasing heat energy with which they do work.
5. Plenty of air is necessary if the human body is to do good work.

THOUGHT QUESTIONS

1. Why will stepping on a burning match put it out?
2. Why will blowing on a slow fire with bellows make it burn faster?
3. Why are the products of burning substances always compounds?
4. A boy breaks his pencil and then throws it into the fire. What kind of change took place in each case? How do the kinds of change differ?
5. Why is it often uncomfortably warm near the ceiling of a room?
6. Why is it dangerous to pour gasoline in a room where there is a flame, even though it be at the opposite end of the room?
7. When a lamp is lighted water is found on the inside of the chimney almost immediately after it is placed on the lamp. Explain.
8. What is the disadvantage of burning gas grates or gas heaters in a living room?
9. Describe briefly the differences in the apparatus used by an insect, fish, and man in respiration. Why does man need more air than either of the other two animals?
10. Give three reasons why your sleeping room should be well ventilated.
11. Hold a burning match at the top and then at the bottom of an open door. Explain what happens.
12. Why should one cover with a blanket a person whose clothing is on fire?
13. How does the gas coming from a fire extinguisher put out a fire?
14. What must be done to make a furnace fire burn well? Can you now see any more clearly the importance of proper ventilation of the home?
15. Name three things which will cause air to be impure.

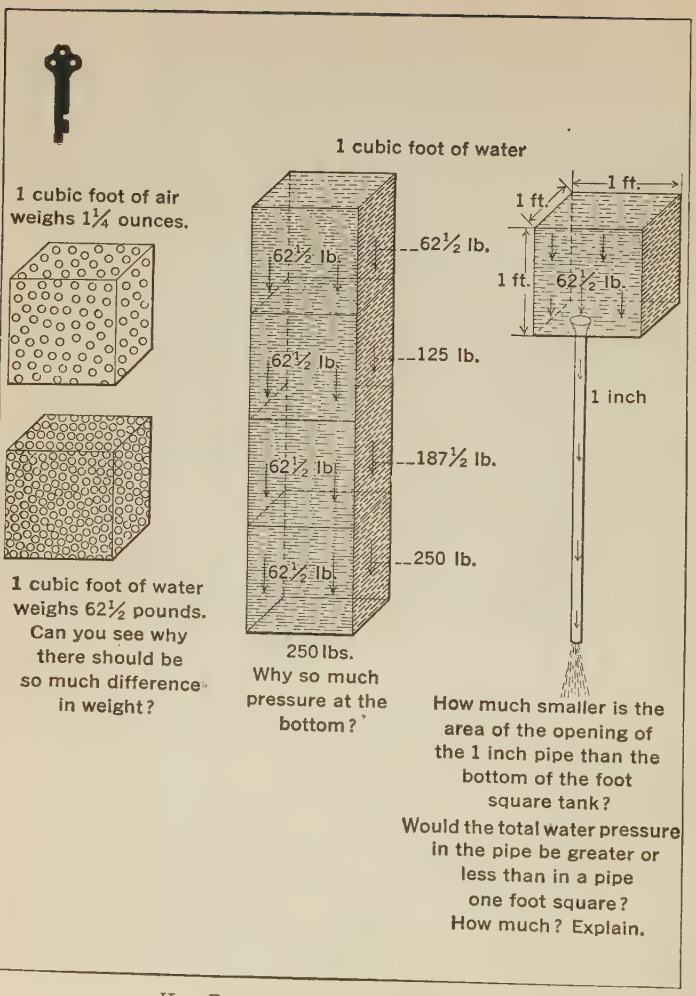
BOOKS WHICH WILL HELP YOU

What boy or girl does not love good books! Knowing this, the author has taken particular care to select, first, the books which will fit exactly the subjects discussed in each chapter and, secondly, the books which will make interesting reading. Most of these books will read like an exciting story. They will tell you what is going on in this great and lively world about you. They will tell you things which you never dreamed could be so. They will excite your desire to know more about your environment and the work of the world. At all times they will be useful to you in solving problems and in giving you suggestions for new problems. With their help, you will be able to add many more special problems of your own to the lists furnished you in this text-book.

Above all, read these books with a purpose. Read them because they give you real pleasure. Read them because they will give you power to know and to enjoy your world.

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Allen. Sweden and Safety Matches. Ginn and Co.
Clarke. Boy's Book of Chemistry. E. P. Dutton and Co.
Fabre. Wonder Book of Chemistry. Century Co.
Fisher and Fisk. How to Live. Funk and Wagnalls Co.
Jameson. The Flame Fiend. Allyn and Bacon.
Jewett. Good Health. Ginn and Co.
Mason. The Origins of Inventions. Charles Scribner's Sons.
Red Cross First Aid Book. Blakiston and Co.
Weeks. The Avoidance of Fires. D. C. Heath and Co.


1 cubic foot of water
1 cubic foot of air weighs 1¼ ounces.
1 cubic foot of water weighs 62½ pounds. Can you see why there should be so much difference in weight?
62½ lb.
62½ lb.
62½ lb.
62½ lb.
62½ lb.
62½ lb.
125 lb.
187½ lb.
250 lb.
250 lbs. Why so much pressure at the bottom?
1 ft.
1 ft.
1 ft.
62½ lb.
1 inch
How much smaller is the area of the opening of the 1 inch pipe than the bottom of the foot square tank?
Would the total water pressure in the pipe be greater or less than in a pipe one foot square? How much? Explain.

KEY PICTURE 6. — WATER PRESSURE.

Why do equal volumes of air and water differ so much in weight? Much of the value of water is based upon its weight. Weight gives pressure and pressure gives force. Even in the washing of clothes the weight of water is of great importance. Consult this picture often as you study this chapter.

CHAPTER VI

THE USE OF WATER IN THE HOME

'Tis rushing now adown the spout
And gushing out below,
Half frantic in its joyousness
And wild in eager flow.
The earth is dried and parched with heat
And it hath longed to be
Released from out the selfish cloud
To cool and freshen me.

— Elizabeth Oakes Smith.

How Much Do You Know about the Rain?

Where does the rain come from? Where does the water come from that flows along the small streams and in the big rivers? Do you know where the water in your well comes from? What is the source of the water which comes from the faucet in your kitchen? Do you believe that you could get along without water? With the help of your father and mother make up a list of the ways in which water is used in your home.

Some Practical Questions:

1. Why is artesian well water usually free from pollution?
2. Why do waters differ in taste and odor?
3. What causes water to flow in an artesian well? in a water system?
4. What will cause the reduction of water pressure in your home?
5. Why do people use more water now than they did twenty years ago?

Home Problem. — 1. Turn on the cold water faucet on the second floor of your home. While it is running have someone open a faucet in the kitchen. Observe the results. Explain them.

2. Compare the flow of water from the cold water faucet at 7 A.M. and at 6 P.M. Explain the difference, if any.

3. Fill a glass of water from the cold water faucet and note if you see any bubbles rising in it. Drink this water at once. Note its taste. Take a second glass and allow it to stand over the stove until all the bubbles are driven out. Place in the ice-box to cool. Drink and compare with the first glass and explain the difference.

Field Problem. — During a rain observe the water flowing along the gutter. Trace this water in its course and tell all the things that might happen to it on its way to the ocean.

THE PICTURES IN THIS BOOK

The illustrations in this book are made for you and no one else. They were drawn for the purpose of showing to you clearly what pages of text could not make plain to you. They do more than this. They offer real problems for you to solve. By trying to answer the questions under each picture, you will take greater interest in it because it will mean more to you. It will become full of life. If you study each picture until you understand it and can then tell its story, you will fix its meaning in your mind so that it will stay. Make full use of these pictures.

1. What Makes Water Flow?

127. Our Dependence upon Water. — Of all the factors of our environment which we use daily, water is the most wonderful, because like a magician it can do so many different things. Properly controlled, it will perform much valuable service for man and his fellow creatures. It is so common that we give it little thought, yet lacking it, life would cease in a very short time. Why? What anxiety follows when city or town dwellers sometimes get a notice to draw

enough water for the needs of a few hours, as the water is about to be shut off! What worry follows the announcement that dry weather may produce a shortage of water in the reservoir (rĕz′ĕr-vwôr). We drink it, cook our foods with it, wash our clothes and bodies with it, warm our homes with it, carry out the house wastes with it, cool our foods with it, and clean our homes with it.

128. Forms and Properties of Water. — Water as we commonly know it is a liquid. For this reason, as it rushes down a hillside, it can fit into any space open to it; it will take the shape of any container which may be holding it, simply because the molecules of which it is composed slip and slide about each other and are not held closely together. Water, because it is liquid, will flow. It also takes different forms. Ice, a solid, and steam, a gas, are both forms of water at extremes of temperature. Try to make up a list of the properties of water.

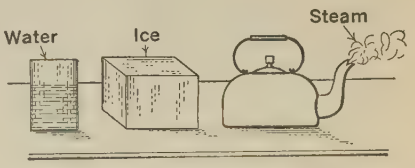


FIGURE 60. — THREE FORMS OF WATER.
What conditions make each form possible? Of course, steam is invisible, but as it condenses it produces little clouds of vapor as here pictured.

129. The Sources of Water. — When you drink a glass of water, you think very little of its origin, — it comes from either the well or the faucet. If someone asked you how it got into the well or the faucet, you might be at a loss to know how to answer the question. It often rains. Rain all comes from the clouds. But in winter this rain may take the form of snow or sleet and sometimes in summer it may fall as hail — yet it is all water and we call the falling of any form of water *precipitation*. But where did the water come from before it fell as rain ?

130. Evaporation and Water Supply. — Under the influence of the sun's heat, water passes off into the air through

the process of *evaporation*.[1] The amount of water carried up into the sky from lakes, streams, and the ocean by this process is enormous. Again, the soil loses much water by the same process. Finally, a continual stream of water vapor is passing into the air from plants.

FIGURE 61. — EROSION OF SOFT ROCK BY WATER.

During heavy rains the water coming down this gorge is deeply discolored. Why? Small pieces of the rock here shown are also carried with the water. Explain.

Even animals give off large amounts of water. But remember this: It is the same water that fell a few days before during a rain and this same water may again fall as rain during the next storm, may again be used by plants, and again be evaporated from the soil and bodies of water. Can you now explain this?

[1] Evaporation: the passing off into the air of a liquid in the form of a gas or vapor.

131. Water Distribution. — It is well known that most of the water which comes down in a hard shower does not evaporate, and does not, because of the rapidity of its flow, have a chance to sink into the ground. This is called *surface water* or *run-off*. It carries with it particles of earth and becomes discolored. It is the run-off that carries away the land in the process of *erosion* (Fig. 61), and carries many minerals

FIGURE 62. — THE WORK OF FLOODS.
What is the chief cause of such floods? How may this condition be changed?

in the soil out to sea, depriving plant life of them. It also builds up the lowlands and tears down the highlands. To prevent this destructive work is one of the greatest problems of the farmer. Our own government is faced every year with the problem of preventing the loss of millions of dollars' worth of property by the destructive work of floods (Fig. 62). The Ohio and Mississippi rivers every spring overflow their banks because of an excess amount of run-off. To control this condition, cities along these rivers are now building embankments and covering with forest trees the bare lands

where these streams begin. How does this practice help to prevent floods?

You may well ask yourself this question: Why does water do such damage? How can it break down dams and carry away trees and houses? As a young scientist, you know that there is but one good way of answering these questions. That way is by experiment.

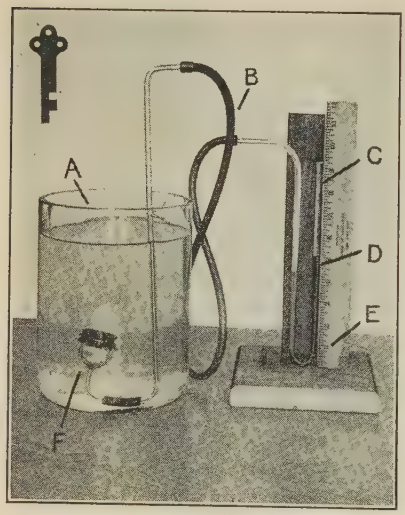


FIGURE 63. — (KEY) DEMONSTRATION 17.

A, jar of water; **B**, rubber tubing; **C**, "U" tube of glass; **D**, red ink in "U" tube; **E**, scale; **F**, thistle tube covered with rubber tissue.

Explain the use of each part of the apparatus here shown. Explain why the parts are assembled as you see them here.

(Key) Demonstration 17: ***Problem: Does water exert pressure upon surfaces?***

Materials: A thin board 1 × 2 feet; a battery jar nearly full of water; a thistle tube; rubber tubing to fit small end of tube; red ink; a glass "U" tube about 8 inches long; a piece of rubber tissue about 3 inches square; some fine cord; and glass tubing. (Fig. 63.)

Method: Fasten the "U" tube to the board as shown in the diagram. Fill the tube half full of red ink. Attach the rubber tubing to one end of the "U" tube. The other end of the tubing should be attached to the extra piece of glass tubing. This in turn is spliced to the shortened and bent stem of the thistle tube. Finally, fasten the square of rubber tissue securely over the bell of the thistle tube. Now lower the membrane into the jar of water very gently. Watch the red ink. Near the bottom turn the thistle tube sideways.

Observations: Does the depth of the bell of the thistle tube in any way affect the height of the column of red ink in the "U" tube? What is in the tube between the rubber tissue and the red ink? What causes the red-ink column to change position? Where is

pressure exerted in the jar? What makes this pressure? Why does it differ? Is it the same, no matter in what position the bell of the thistle tube may be placed at any one level? What does this prove to you?

Conclusion: Record your conclusion. Give your proofs.

Practical Application: What connection has the caisson (p. 95) with the conclusion of this demonstration? Why can submarines go only to a certain depth under water? Why do divers have their air-lines strengthened with steel wire? (See Key Picture 6.)

FIGURE 64. — THE WATER CYCLE.

A, spring; **B**, artesian well; **C**, pond; **D**, rock strata; **E**, soil; **F**, cavern formed by water; **G**, bed rock.

Explain how and why water makes a complete cycle here.

132. Gravity and Flow of Water. — Gravity causes rain to fall from the clouds and to run down the hillsides with great rapidity and force. The weight of water gives it this force. This sends it down deep into the soil. Water which soaks deep into the soil is called *ground water*. The level where such water is held in large quantities is called the *water table*. This is the source of *springs* which bubble clear water from the side of a hill (see Fig. 64). When water flows from a spring into a house there is not much weight

behind the small stream running through the pipe. But when a large body of water has only one outlet, namely, an opening into a small pipe, it is like a large group of boys trying to get through a narrow door all at the same time. There is sure to be crowding or pressure and some of them will shoot out of the door in a hurry due to the pressure behind them. Why is little water pressure needed for a few families? Why must there be great water pressure in a city? (Key Picture 6.)

133. Town and City Water Supply. — Its uses in cooking, washing, cleaning, in steam

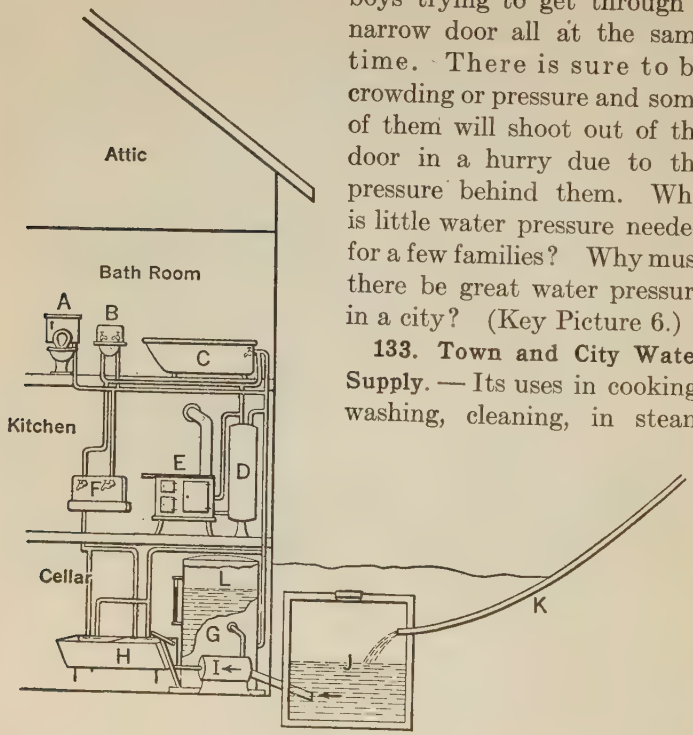
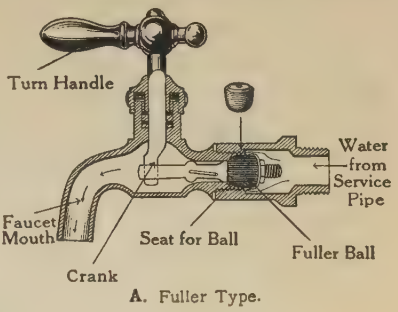


FIGURE 65. — THE PNEUMATIC TANK.

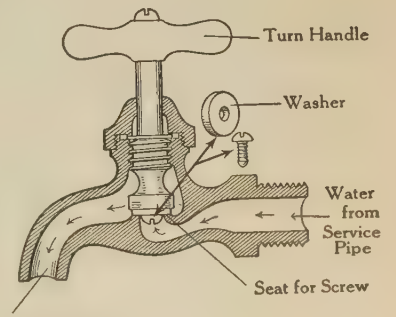
An efficient method of sending water where you want it in a country home. Try to give the name of each lettered part. Why does the water enter the tank G? Explain. Why does it rise in the house pipes?

and hot-water plants, in driving water motors, in flushing toilets and sewers, in cooling, in watering the garden and in sprinkling the lawn make the supplying of enough water to large cities a big problem. So many uses of water mean a large per capita consumption, larger than most people be-

lieve. In Philadelphia the average daily amount used by each person is 170 gallons; in Pittsburgh it is 197; in Chicago it is 237 and in New York 95. Multiply 95 by 6,000,000, the number of people in New York, and you have a total of 570,000,000 gallons a day. How far would wells go in supplying this enormous amount of water?



A. Fuller Type.



B. Screw Type.

FIGURE 66. — TWO TYPES OF FAUCETS.

Which do you think the better? Give the functions of each part. Learn how to repair your faucets.

2. How Is Water Used in Your Home?

134. House Distribution of Water. — In most cases pumping water from a well merely raises it to the platform of the well. It must still be carried to the house. Many enterprising persons use a force pump to pump this water to a tank or reservoir in the attic of the house, from whence it flows through pipes to the faucets by gravity. This pump may be worked by hand, windmill, gas engine, or electricity. A more improved method is that of the pneumatic tank [1] system, which does not require the use of an attic tank. Study Figure 65 and explain it after an-

[1] Pneumatic tank: a tank containing compressed air.

swering all questions. The gravity system of house distribution of water is, of course, the simplest and most inexpensive. But with this advantage goes much inconvenience, owing to the fact that generally the water must be piped from an elevation to get the proper force of flow and this means much friction, pipe repair, and often pipe obstructions.

135. Control of Water Flow in the Home. — Every properly installed water distributing system in the home has a stop and waste cock inside cellar wall. Why not

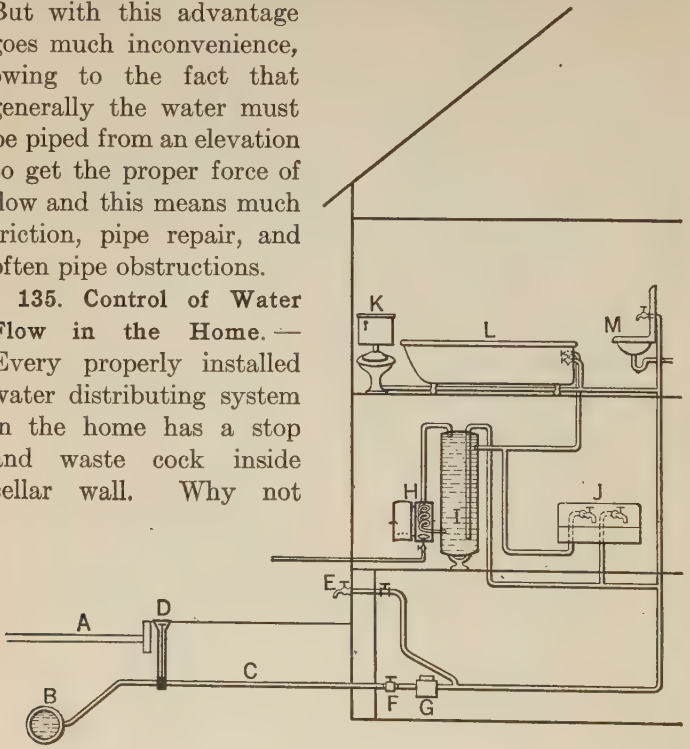


FIGURE 67. — HOW WATER IS SENT INTO AND ABOUT THE HOME.

A, pavement; **B**, water main; **C**, service pipe; **D**, street shut-off valve; **E**, sill cock; **F**, cellar cut-off valve; **G**, meter; **H**, hot-water coil; **I**, hot-water heater; **J**, kitchen faucets; **K**, toilet flushing tank; **L**, bath tub; **M**, wash bowl. Give the use of each part here shown. Note how the parts are all connected in one system.

outside? Where a branch runs to the heating plant, a wheel valve is generally placed. Explain. At the point where the main pipe rises through the floor a second wheel valve is often placed. Why? Two turncocks are to be found on the pipe leading to the connection with the garden hose —

one inside and the other outside the cellar wall. Explain. The final control is found in the faucet (Fig. 66) at the end of each of the smallest pipes. Study Figure 67 until you understand the water distribution plan in a home.

136. Uses of Water in the Home. — So far, you have been interested in the way water gets into your home because of its value to you as a beverage. But the amount of water you drink in a year is very small in comparison with the amount of water you use in your home in a year. On

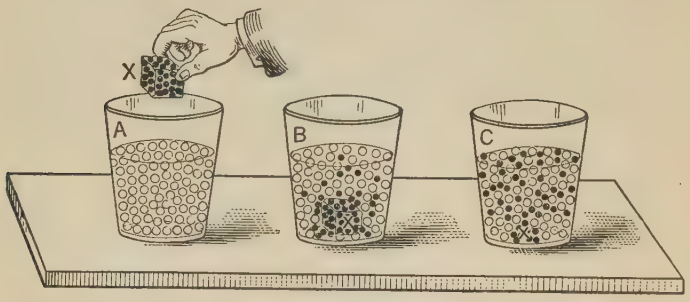


FIGURE 68. — HOW A SOLUTION IS FORMED.

Why is water necessary? What happens to the smallest particles of sugar? Why can they not be seen in a solution?

page 161 we saw that in New York City 95 gallons are used on the average by each person each day. What is the use to which all this water is put? Make a list of as many uses of water as you can remember. Keep in mind as you make up your list that water is not always used alone but is often mixed with other substances.

137. The Nature of a Solution. — In a cup of sweetened water the sugar crystals are separated by the water into extremely small particles. After some time these particles tend to become equally distributed through the liquid. When this distribution has been completed, then you have a solution. Sugar is a *soluble* substance, upon which water acts

as a *solvent*. The dissolved sugar is called a *solute*. Starch on the other hand is an *insoluble* substance; that is, the water or solvent cannot separate the particles of which the starch is composed, — cannot get between them and cause them to disappear through making them small. *A solution, then, is a clear, uniform mixture of a solid and a liquid which do not separate when filtered or allowed to stand.*[1] What really happens when you put sugar in your coffee? How do you know that the sugar is still there? (Fig. 68.)

(Key) Demonstration 18: ***Problem: What is meant by "hard" and "soft" water?***

Materials: Rain water; glass tumbler; faucet water; soap; several beakers; Bunsen burner; iron tripod; and borax. (Fig. 69.)

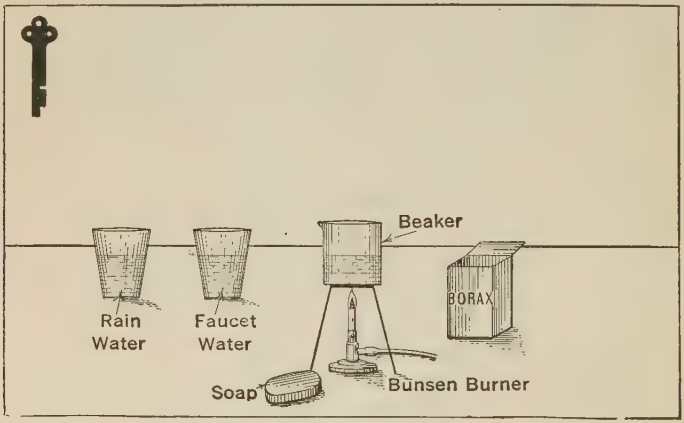


FIGURE 69. — (KEY) DEMONSTRATION 18.

Explain why each part you see here is used. How is each used?

Method: A. Dip the fingers in some rain water in the tumbler. Rub them together. Note the "feel" of the water. This is "soft" water.

B. Test some well water or faucet water the same way. What is the difference? This is probably "hard" water.

[1] In a similar manner gases and liquids may be said to dissolve in water.

C. Heat some soft water in the beaker and shake some soap in it.

D. Heat some of the hard water and shake some soap in it also.

E. Boil some of the hard water. Does it change its "feel"?

F. Dissolve some borax in some hard water. Test with the soap. Note the results.

Observations: What effect does soft water have on soap? Do suds appear in hard water as readily as in soft water? If a scum appears upon the water and the suds are scanty, you may know that the water is hard. This means that minerals are dissolved in it. What effect did boiling have on the hard water? If no suds appear when soap is used, the water is *permanently hard.* If a few appear, the water is *temporarily hard* and boiling makes it soft. What effect does the borax have upon the hard water? How do you suppose it acts?

Conclusion: What do you think is the difference between hard and soft water? How can you make hard water soft? Give your proofs.

138. Hard and Soft Water in the Home. — The water of some regions is so hard that it is impossible to make suds with it. Thus it is difficult to wash clothes thoroughly with it. Soap used in hard water merely combines with the salts in it to form an insoluble, sticky scum. In this condition it has no effect upon the grease or oil in the clothes, and no cleansing is possible. Homes where hard water is in use waste large quantities of soap. To save soap and to insure the maximum amount of cleansing, washing soda, which unites with the calcium or magnesium salts in the water, should be used. Thus these salts are prevented from uniting with the soap, leaving it free to cut the grease and remove the dirt.

Care should always be taken in the use of washing sodas, however, as they are strongly alkaline,[1] and if they become concentrated in any one spot in a heap of soaking clothes (particularly woolen), they will eat holes in the clothes and destroy them. Dissolving the washing powder in warm water before putting it in with the clothes will prevent this con-

[1] An alkaline substance is one which will turn red litmus paper blue.

centration and will make more effective the work of the powder. Laundries are often careless in this one point and the too rapid fraying and easy tearing of clothes are due to these powders. Borax is an even better softener than washing powders and cannot possibly do any harm, but it is somewhat expensive for general laundry use.

When hard water is used for bathing purposes, an unpleasant result is the formation of a sticky scum along the sides of the bath tub, which soap will not easily remove. A very small amount of scouring soap placed on the washcloth will completely remove the scum with very little work. The formation of this scum may be prevented by placing in the bath water a few drops of household ammonia and a small amount of borax, before using it. Explain.

139. Cleaning of Clothes in the Home. — If water comes in contact with plain dirt lodged in cloth, it breaks up this dirt into smaller particles, separates them, and washes them out. But the skin, underwear, and other garments which touch the skin cannot be cleaned with water alone, because the skin is covered with oil coming from the oil or sebaceous (sĕ-bā′shŭs) glands, and this oil works into the clothes. Dust and dirt are caught by this oil and lodged in the clothing and on the skin. Water alone will not affect this mixture. Soap, then, must be used.

On applying soap, which contains some glycerine, the grease is broken up into very fine droplets, each droplet is surrounded by a film of soap, thus forming an *emulsion*, and the water separates these droplets and carries them off.

Find out what kinds of soap and washing powders your mother uses. Find out what they are composed of. Ask your mother why she prefers some kinds to others. Determine the good qualities of some of the soaps and powders and report to your class upon them.

140. The Effect of Water on Foods. — Water enters largely into the composition of all green vegetables. Some,

such as lettuce and cabbage, contain as much as 95% of water. This water makes them fresh and palatable.

Soaking dry groceries such as beans, cereals, and dried fruits in water softens them and dissolves out the dried juices, thus restoring some of the freshness of their original flavoring. Meats and vegetables when soaked in water lose much of their toughness. In parboiling meats, the hot water dissolves out excess substances, such as the salt in ham. In a stew, most of the flavors and juices are driven out into the water. This produces soup, which is partly a solution and partly an emulsion. Soups are nutritious (nūtrĭsh'us) and easily digested. Besides, they are inexpensive.

Meats often contain bacteria. Pork may be infected with a small, round worm called the *trichina* (trĭ-kī'nȧ), which, when taken into the body in meat, burrows into the tissues and causes pain and sometimes death. *Tapeworms* are also likely to be hidden in meat not thoroughly cooked. Water washes off vegetables, thus cleaning them. Boiling vegetables and meat in water kills the bacteria and other harmful organisms.

141. Heating Water in the Home. — Hot water is now in many ways more essential in the modern home than cold water. To procure large quantities of hot water when needed, many devices are used, but the most common one is the hot-water heater. Every boy and girl should know the principle upon which it works.

(Key) Demonstration 19: ***Problem: How does the hot-water heater work?***

Materials: A piece of glass tubing 1 inch in diameter and 8 inches long; two rubber stoppers to fit this tube (one with one hole, the other with three holes); glass tubing to fit holes in the stoppers and bent and fitted as shown in Figure 70; a thistle tube; a Bunsen burner; an iron ring stand; and water.

Method: Set up the apparatus as shown in the diagram. Fill the tube with water. See that the circuit is full. Gently apply the Bunsen flame to the lower elbow of the glass tubing. Watch for results.

Observations: What happens to the water in the circuit? Feel of the glass cylinder every few moments. What do you note? How do you explain what you observe? Feel of the tubing in several places. What do you find out? In the home hot-water boiler what corresponds to the Bunsen flame? Why is the thistle tube used? What takes the place of this in the house?

Conclusion: Write out in full what you think is the principle upon which the hot-water boiler works. Give your proofs. Can you explain why the supply of hot water becomes greater all the time the coil is being heated? Explain fully. (See Key Picture 6.)

Practical Application: Discover any other way in which the principle discovered here is used in your home.

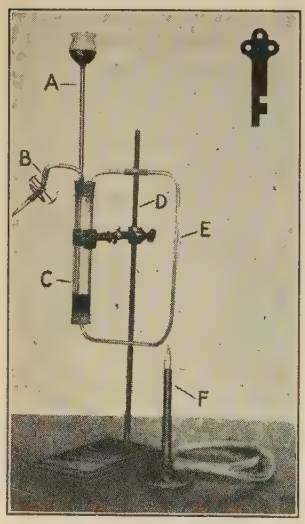


FIGURE 70. — (KEY) DEMONSTRATION 19.

A, thistle tube; **B**, overflow tube; **C**, glass tube; **D**, ring stand; **E**, glass tube; **F**, Bunsen burner.

142. The Hot-Water Heater. — All softeners of dirt and grease work more rapidly in hot water. Explain this. Consequently, we see the great need of hot water in the home of to-day. The hot-water heater (Figure 71) is commonly attached to the cold water supply on one side and to the coal stove, oil, gas, or electric heater on the other side. Automatic hot-water heaters are now in common use. In such devices a thermostat opens or closes a series of gas jets, thus assuring a constant supply of hot water.

143. The Use of Water in Heating Systems. — In many homes the hot-air furnace fails to send heat to the rooms in regular and even quantities. If some substance could be found that could be made to flow to every room in the house and there give off heat, all the weakness of the hot-air furnace could be overcome. Knowing that heated water circulates,

what could be easier than to use heated water and allow its heat to radiate into each room through radiators?

Demonstration 20: *Problem: How is heat carried by steam or water from one place to another?*

Materials: A Florence flask; a two-holed stopper to fit; two thermometers; bent glass tubing; an iron ring stand; a Bunsen burner; a beaker; and water.

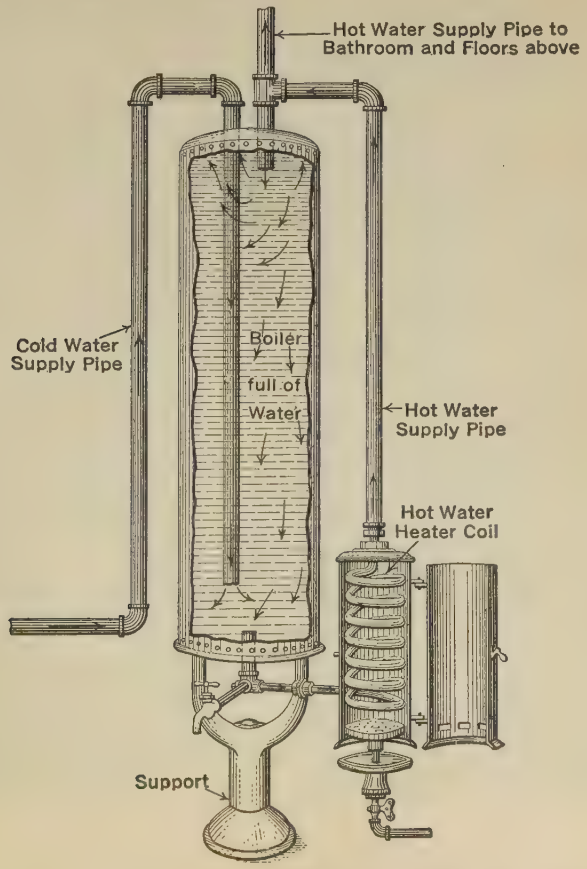

Hot Water Supply Pipe to Bathroom and Floors above
Cold Water Supply Pipe
Boiler full of Water
Hot Water Supply Pipe
Hot Water Heater Coil
Support

FIGURE 71. — THE HOT-WATER HEATER.

Compare this picture with the apparatus used in (Key) Demonstration 19 How are they alike? How are they different? Explain the arrows.

Method. Set up apparatus as shown in Figure 72. Fill flask and beaker each about one-half full of water. Note thermometer readings in each receptacle. Bring water in flask to boiling point and keep boiling with a steady, even flame. Observe the thermometer readings from time to time. When the thermometer in the beaker reads about 40° F., remove the beaker and the flame.

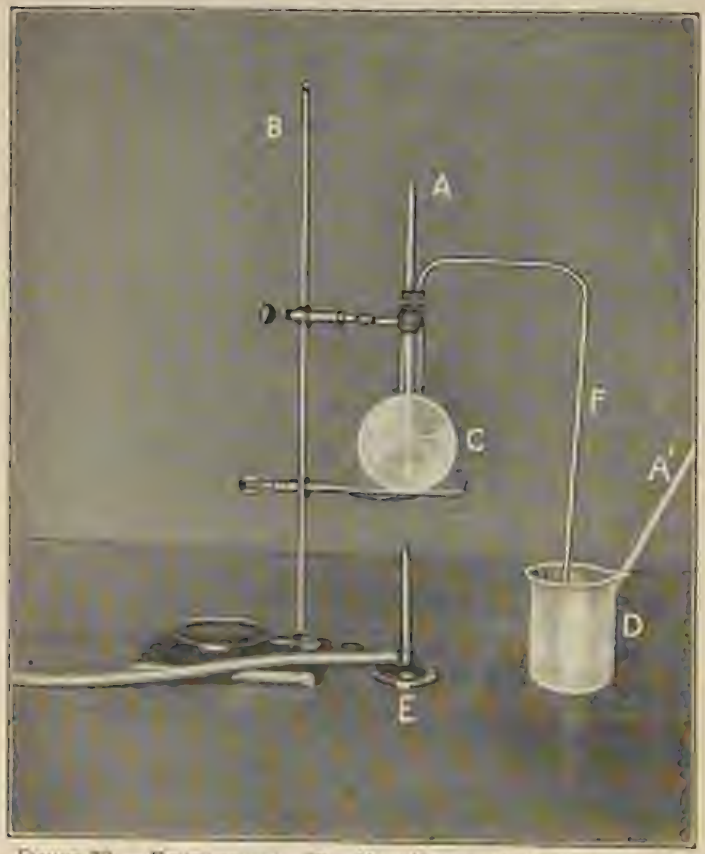


FIGURE 72.—DEMONSTRATION 20. HOW HEAT MAY BE TRANSFERRED.

A, A', thermometers; B, ring stand; C, flask of water with two-holed stopper; D, beaker; E, Bunsen burner; F, glass tubing.

Be sure you understand just how the parts are used before you try the experiment.

Observations: Was any heat transferred from the glass to the beaker? What carried it over? This changing of water into steam is called *vaporization* and much heat is carried with the steam wherever it goes. What happened to the steam in the beaker? When steam is changed into water, the process is called *condensation.*[1] Much heat is given up in this process. How do you know?

Conclusion: Draw your conclusion. Give proofs.

Practical Applications: What would happen if the beaker were replaced by a flask and the two connected so that water could freely return to the flask being heated? Study a steam heating plant in a building and determine how it works.

144. The Steam Heating Plant. — A boiler in the cellar partly filled with water and capable of being heated, so that the water can be vaporized into steam and sent up into the radiators in the rooms of the house is the principal part of a steam heating plant. This steam under pressure takes heat with it and on reaching the radiators condenses into water, leaving the heat behind. The water then returns by gravity to the boiler to be vaporized again. Study carefully the diagram of this system in Chapter VIII, page 241, and be able to explain it.

145. The Hot-Water Heating Plant. — In the hot-water plant the water fills all the pipes and carries heat to the radiators, where it is given up to the rooms. The expansion (ĕks-păn′shŭn) of the heated water causes it to circulate slowly and evenly throughout the system. At the top of the building an expansion tank must be connected with this system. Can you see why? What are the advantages of this system over the steam heater? the disadvantages? Study Figure 118 to understand this system.

146. Cold Water and Ice. — In the modern home we now find that cold water and ice are of almost as much importance as hot water.

Ice has come within recent years into such great demand as a preserver of foods that the natural supply is not great enough to meet the demand. Artificial ice has now largely

[1] Condensation: the changing of a gas to a liquid.

taken the place of natural ice because it can be manufactured during the whole year; in most cases pure spring or distilled water is used to make this ice.

147. How Is Ice Manufactured? — If much heat can be taken out of large volumes of water in a very short time, ice will form. How do you suppose that this can be done? Why not try an experiment yourself to find out?

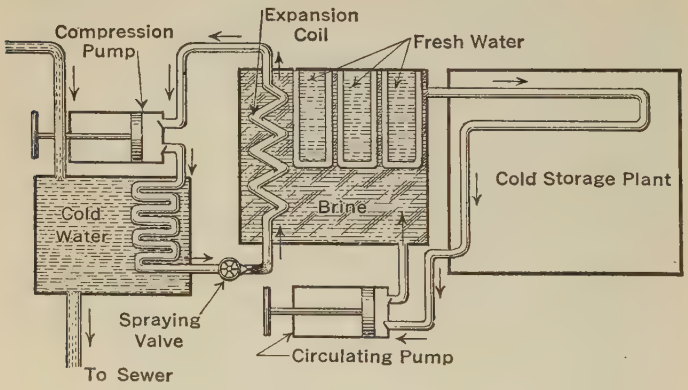


FIGURE 73. — SECTION THROUGH AN ICE MACHINE.

Study each part carefully. See the connection between the parts. What brings the ammonia from the expansion coil to the compression pump? Note the way the valves work. Explain. What causes the ammonia to turn into a spray at the spraying valve? What happens to the ammonia as it expands? How does this affect the fresh water in the cans? Note the valves in the circulating pump. How do they work? How is the cold storage plant kept cold?

Suggested Experiment.—Get a small quantity of ether. (*Warning! There should be no flames in the room while the ether is in use.*) Also secure a flat cork, a watch glass, and some water. Now place a small quantity of water on top of the cork, set the watch glass on this water, and fill the bowl of the glass with ether. Cause the ether to evaporate by blowing the breath gently across it and then pick up the glass. What has happened? Pull the cork and watch glass apart. What do you find? What caused this result? Why will sprinkling the streets on a hot day cool them? Why will moistening the face on a hot day cool one? Why will bathing a sick person with alcohol tend to reduce the fever?

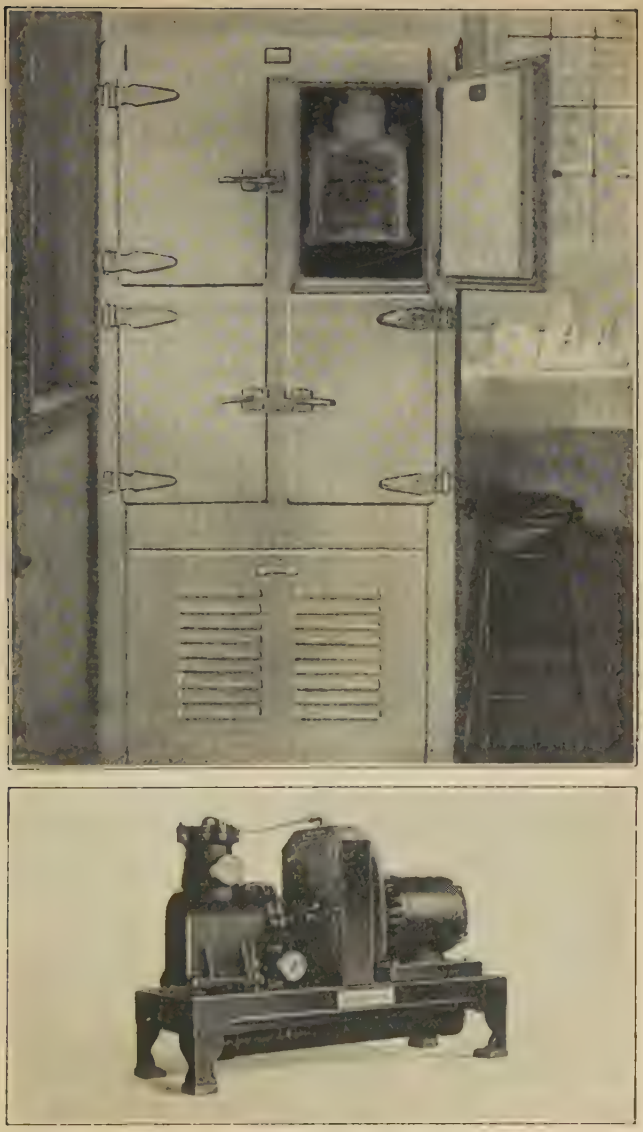


FIGURE 74A. — THE ELECTRIC REFRIGERATOR.

Above. The food cabinet with door of ice-unit open. *Below.* The motor.

The electric refrigerator illustrates a modern method of home refrigeration. Its principle is simple. You know that water boils ordinarily at 212° F., but that in a vacuum or at high altitudes (page 230) it boils at a lower temperature. In a vacuum, water may be made to boil without a fire, the evaporating water carrying away much heat. This is just what happens in the electric refrigerator. A high vacuum is produced in the evaporator E by the pump A, commonly placed in the cellar. This vacuum causes the liquid refrigerant (usually ethyl or methyl chloride) to evaporate at a rapid rate as it enters the evaporator, absorbing heat from the air in the refrigerator and carrying it down the pipe G to the condenser H in the cellar. Here a cooling unit (water cell, honeycomb radiator H, coils, or fan I) condenses the vapor to a liquid. It is then pumped back to the evaporator through pipe B and valve D which opens when the pressure in the condenser is a certain number of pounds greater than it is in the evaporator.

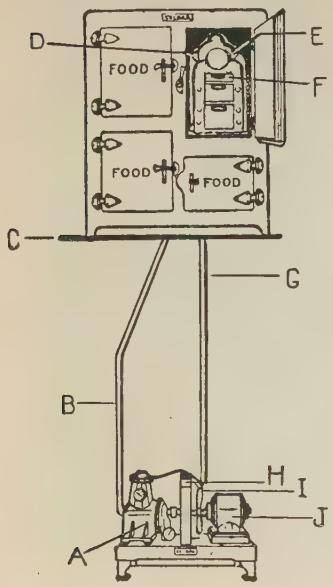


FIGURE 74B. — DETAIL OF ELECTRIC REFRIGERATOR.

The pump and fan are operated by an electric motor (J) controlled by a thermostat. C marks the floor between cellar and kitchen and F points to a tray of ice cubes.

A still more recent method of refrigeration requires the use of a gas flame — "the flame that freezes." Here the flame evaporates the refrigerant, resulting in the withdrawal of heat and a tiny jet of cold water condenses the gas into a liquid again. No motor is required in this system.

148. Ice Machines. — Whenever a liquid is quickly changed to a gas, heat is absorbed from the object nearest it. Ammonia is a gas, which, when liquified, will quickly evaporate, thus absorbing heat, and it is relatively cheap. The ice machine was, accordingly, invented to use this ammonia. Its principle is simple. Study Figure 73 and explain it.

149. Refrigerating Plants. — Cold storage plants with their ice machines are used to preserve large quantities of meats, eggs, butter, vegetables, and similar foods. Before such plants came into use, millions of dollars' worth of foods rotted because there was no means at hand to prevent their decay. Nor could a shortage of certain foods, when they were not in season, be avoided.

Were it not for the cold storage plant and the refrigerator car, little western beef would be found on the tables of people living in the eastern states nor would the Florida and California fruits be on sale in New York and other cities.

FIGURE 74c. — HOW THE REFRIGERATOR WORKS.

Why does the air circulate? What does this circulation do for the foods? Explain.

150. The Home Refrigerator. — While hot water dissolves substances, ice congeals them. It prevents their melting and serves to keep them from spoiling. The ice in the refrigerator as it slowly melts absorbs the heat from the materials and air in the refrigerator. The result is that bacteria grow more slowly in the food exposed to such cold air. It is readily seen, therefore, that a saving of ice and of foods requires that the refrigerator doors shall not remain open a moment longer than is necessary to put

in ice or put in or take out foods. Hot foods should not be placed in the box. Study Figure 74c and explain the principle of the refrigerator.

151. The Freezing of Ice-Cream. — Many families now consider the house equipment incomplete without an ice-cream freezer. You have seen people put salt on icy walks. The salt melts the ice at a temperature below the usual melting-point. This ice in melting absorbs heat.

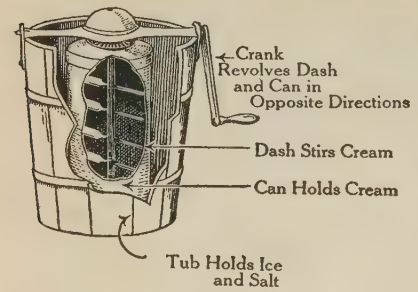


FIGURE 75. — HOW THE ICE-CREAM FREEZER WORKS.

Why is the can metal and the tub wood? What is the use of the dash? the crank?

Now in the ice-cream freezer (Fig. 75), the salt acts on the ice in the same way, and in doing its work here it requires heat. The source of heat here is the cream to be frozen. Answer questions on the picture and be able to explain it.

3. How Used Water Is Taken from Your Home

152. Water and Wastes in the Home. — Most of the water which passes out through the waste system contains impurities dissolved or suspended in it. These may come from the human body wastes, from soiled clothing, dirty hands, dirty dishes, vegetables, dust, or many other sources. In every case, water made impure by these things is *dangerous*. It is for this reason that a closed waste system must be installed in every home, if the house is to be kept free from dampness and disease.

153. Simple Methods of Waste Removal. — In the country the outside toilet is the common method of taking care of the body wastes. The unwholesomeness and dangers of this method of disposal are plain and will be discussed later.

In some rural homes, slops and garbage are commonly thrown out of the back door to dry in the sun, the water sinking into the ground and possibly contaminating a well or spring. There is a fearful danger in such waste disposal and every person ought to know it.

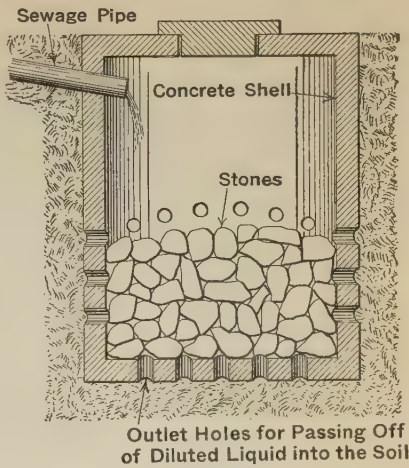


FIGURE 76. — A CESSPOOL.

Explain the use of each part labeled.

Every farm or village home should be supplied with a properly constructed *cesspool* into which all wastes can be flushed by the use of an abundant flow of water (Fig. 76). A more modern apparatus for the disposal of wastes is the *septic tank*. This is made of cement and has three compartments, all water-tight and arranged as a set of connecting tanks. Study Figure 77 until you understand it. (See section 172.)

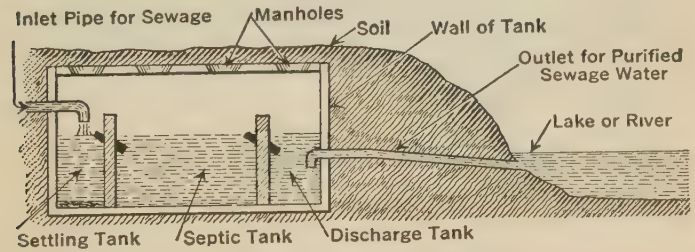
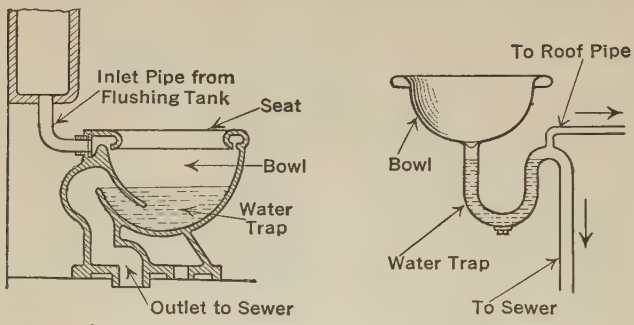


FIGURE 77. — A MODERN SEPTIC TANK FOR HOME OR SMALL TOWN USE.

In the left section the solid parts settle to bottom and decompose. The overflow goes to middle section. Further decomposing goes on. The overflow here is clear. The overflow from the third section is almost free from impurities.

154. Waste Pipes and Traps. — One of the great dangers of the waste system is the sewer air which naturally rises and



A. Toilet Bowl. B. Wash Bowl.

FIGURE 78. — TWO KINDS OF GAS TRAPS IN THE HOUSE WASTE SYSTEM. Where is the siphon in each? What keeps sewer gas out of the bowls? Where is the water seal in each trap?

escapes through the waste openings unless traps are used to stop it. Such traps are really inverted siphons and a seal of water keeps the gas back. A vent leading from the waste pipe below the water seal leads the sewer gas off to a main vent which reaches to the roof. The open plumbing of today has all pipes in sight or easily accessible. They are thus easily repaired and kept in a clean and wholesome condition. Study Figure 78 and answer questions upon it.

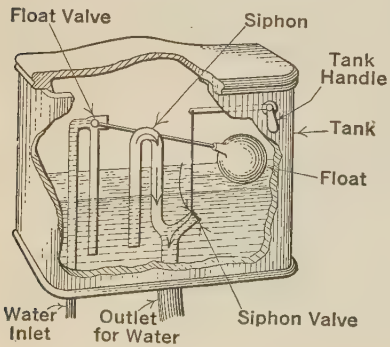


FIGURE 79. — A FLUSH TANK.

Find the siphon. When and how does it work? When and how does the float work? When does the inward and outward flow of water begin and stop? Explain.

It is very essential that all the pipes leading from traps shall be short, direct, and slanting downward at a sharp angle.

Explain. They should also be relatively large. Explain. There should always be a good flow of water through them. Explain. Obstructions of lint and grease are most frequent in the wash tub outlets. If, however, all the waste wash-

Trenton Potteries Company.

FIGURE 80. — A WELL EQUIPPED BATHROOM.

Why is it well equipped? Is the arrangement of the conveniences the best? What are your suggestions?

water, together with a little lye, is poured through these pipes each time a washing is done, these pipes can be kept clean.

In the bathroom there must be a sudden and heavy flow of water to flush out the solid wastes from the toilet bowl. A flushing tank is used for this purpose. A siphon pipe and atmospheric pressure do this work and the turning of a handle

starts the process working. A float automatically opens and closes the entrance for water to fill the tank. Study Figure 79 and fully explain the principles involved.

155. The Modern Bathroom. — A feature of the modern, refined home is the bathroom. It should be conveniently located, away from close contact with the living rooms, dining room, and kitchen. It should be tiled in white and papered or painted to match. It should be kept spotlessly clean and all fixtures should be frequently polished. The washbasin, bathtub, mirror, medicine closet, toilet, foot tub, towel racks, shower bath, lights, and other elements should be appropriately placed for convenience and beauty. Study Figure 80 and make suggestions for changes. It may be said that the wholesomeness and culture of any family is almost surely gauged by the appearance and cleanliness of its bathroom.

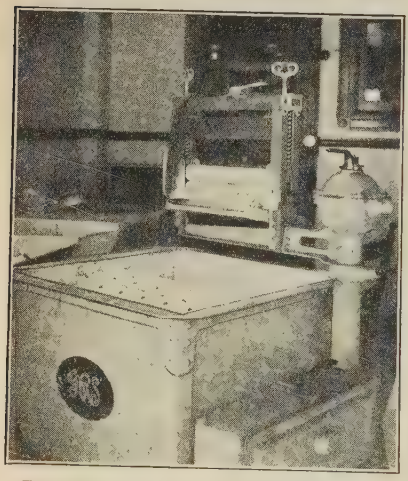


FIGURE 81. — AN ELECTRIC OR POWER WASHING MACHINE.

Note the wooden barrel with its slats and holes. What is their use? What runs the machine? Note the attachment of the wringer.

156. Water and Work. — The washing of clothes in the home is now frequently done by the power washing machine (Fig. 81). In the washing machine, the rotary motion forces or plunges the water through the clothes, carrying with it the dirt. A plentiful supply of good water means great efficiency. Explain.

The convenience, comfort, and efficiency of the modern

home is largely due to the plentiful water supply brought to it. If you enjoy this convenience in your own home, you can readily determine how much you depend upon it by asking yourself what you would do if the water supply were

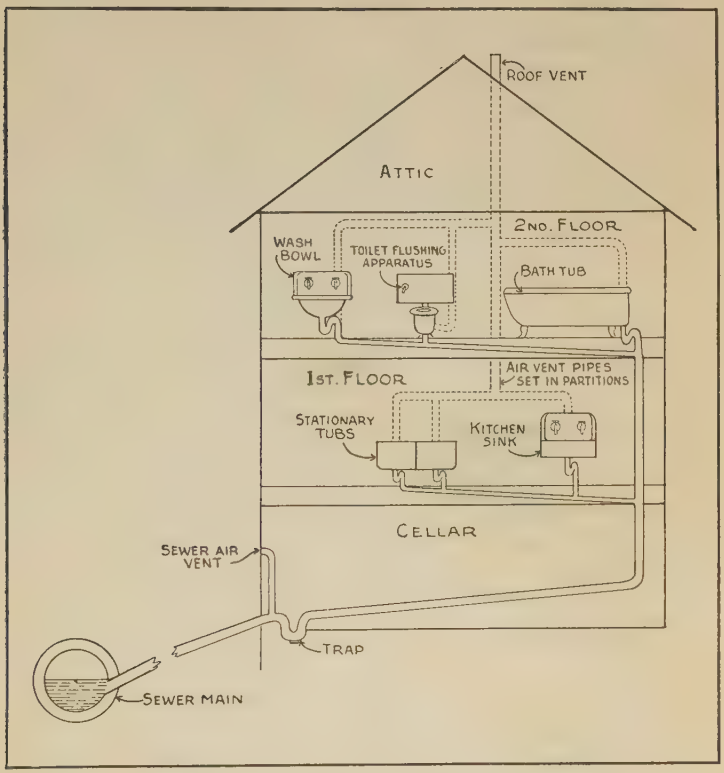


FIGURE 82. — A MODERN HOUSE WASTE SYSTEM.

Note how all the parts are connected, with no openings into the house. Account for the traps and the opening to the roof.

to-day permanently cut off. The very thought of such a disaster makes you pause to consider the many benefits which are yours because of water's usefulness. And you are grateful to science for making possible a pure, abundant supply.

After each of the first five chapters you were given a list of Key Words taken from the chapter. These words were not chosen in a hit-or-miss fashion but with the definite aim of guiding your thinking about the contents of the chapter.

You are now far enough along in the book to do your own selecting of Key Words. As you read, jot down these words and star those of especial importance. Then, after the chapter is completed, review your list and enter the starred words in your Science Discovery Book.

REVIEW OUTLINE

1. Our Dependence upon Water.
2. Sources of Water: (1) rain; (2) evaporation from soil, plants and animals.
3. Forms and Properties of Water: Gas, liquid, and solid. Colorless, odorless, tasteless, heavy liquid. Forms solutions, soaks through fabrics and similar containers.
4. Water Distribution: (1) surface water and erosion; (2) ground water and springs, lakes and ponds, etc.; (3) ground water and artesian wells, etc.
5. Sources of Home Water Supply: (1) on the farm; (2) in the village and town.
6. House Distribution of Water: The piping system. Control of water flow.
7. Uses of Water in the Home in: (1) cleaning clothes; (2) preparing foods.
8. Hot water and Its Uses in: (1) hot-water boiler; (2) steam heating plant; (3) hot-water plant.
9. Cold Water and Ice: Pure ice and its manufacture. Structure, principle and care of the ice cream freezer and refrigerator.
10. Relation of Water to Wastes: (1) methods; (2) waste pipes and drains; (3) the modern bathroom.
11. How Water Does Work in the Home.

SUMMARY

Water is found everywhere — in the *soil*, in the *air*, in *living things*. Through *evaporation* it rises into the air as *vapor* and through *precipitation* falls as *rain*, following a fairly well-defined path or *cycle*. This means that the same water is used over and over again.

When water falls as rain it rushes down the hillsides as surface water, causing *erosion* of soils and floods. Much of it sinks into the ground as *ground water*, to form *springs* that supply *wells*, *ponds*, *lakes*, etc. It is this ground water which forms the chief source of our water supply.

Water being *heavy*, and a *colorless*, *odorless*, *tasteless* liquid, is of great value in the home. It takes different forms and readily makes *solutions*. It may be piped to a home from a spring or distributed through the home by pipes connected with the central water supply system which obtains its water from pure ground water sources.

Water, as a *solvent*, *cleans clothes*, *removes stains*, *washes our bodies* and *our homes*, and *prepares foods for the table*. It may be heated and used to *warm our homes*. Or it may be frozen and placed in the *refrigerator* for *preserving* or freezing foods. Because of its great weight, it is important as a *flushing agent* in removing solid and liquid wastes from the home.

Water is a wonder worker in the home. It makes the modern home possible. It is, with fire, one of the two greatest factors in producing the civilization of to-day.

Remember that :

1. Water because of its form and weight distributes itself over the surface of the earth.
2. The human engine must have pure water to keep it in the best condition.
3. Water is one of the greatest solvents and therefore tremendously useful in the removal of dirt.
4. Water in the form of ice is essential to the proper keeping of foods.
5. Water is essential to the proper flushing of wastes from the home.

THOUGHT QUESTIONS

1. Is water safe to drink because it is clear, colorless, odorless, and cold? Explain.
2. Why is it unwise to use drinking water cooled by melting pond ice in it?

3. How could you purify your home water which you suspected of pollution?

4. What are some of the disadvantages in the use of hard water? soft water?

5. Explain just how you would care for a cistern; a well.

6. Why is it sometimes impossible to draw water on the second floor of a house?

7. Give the advantages and disadvantages of securing drinking water from a spring.

8. Why is water without soap a comparatively poor cleanser?

9. Why is the food placed at the bottom of a refrigerator and the ice at the top?

10. What are the most common causes of the stoppage of water pipes; of waste pipes? What method is best used in the cleaning of each? Explain fully.

SPECIAL PROBLEMS

1. Determine how the water supply is measured in your home.

Suggestions: If you have a water meter determine its location and why it is so located. Study its structure from the outside. Note its unit of measurement. Study an account of its interior in a good text-book or encyclopedia. Open a faucet and then watch the face of the meter. Note the change. Now open two faucets. Is the registering twice as fast as before? Now use the hose. Compare the reading with that shown by the flow of the faucets. Determine the cost of using one faucet one hour. Does this aid you in realizing the need of careful use of water in the home?

2. Determine the amount of water lost through leaking faucets.

Suggestions: If you have a dripping faucet in your home, place a pail beneath it and determine how much water comes from it in one hour. Multiply this amount by 24; by 365. Why? If you have a water meter, determine what this costs you per year at this rate. Now determine, if you pay for your water by the year, what it costs your town or city at the rate of $2 for each 15,000 gallons wasted.

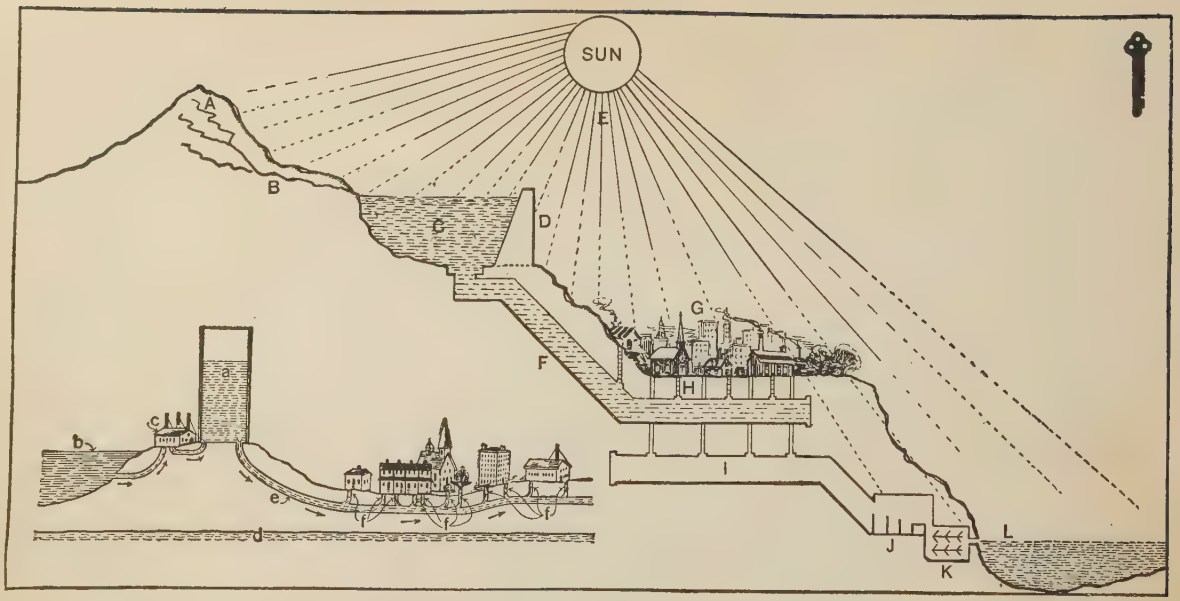
3. Study the structure and working of the water traps and flushing tanks in your home.

Suggestions: Examine the flushing tank in your bath room as to its position, convenience and structure. Find the ball, plunger, siphon, etc. Determine how each works. Make a labeled diagram to show this. Note especially if your tank differs from that shown in the diagram. If it does differ, study the picture shown in the text and determine its principle before reporting upon your own tank.

Study the diagrams of the toilet traps. Which is in your opinion the best trap and why? Examine the refrigerator trap in your home. Make a diagram to show its principles. What seals the water in the toilet bowl? Would you call this a trap? Report the whole problem to the class.

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Butler. Household Physics. Whitcomb and Barrows.
Clarke. Boy's Book of Chemistry. E. P. Dutton and Co.
Fabre. Wonder Book of Chemistry. Century Co.
Fisher and Fisk. How to Live. Funk and Wagnalls Co.
Gates. Farm Water Supplies. Circular 18. Massachusetts State Board of Agriculture.
Hardenburgh. Home Sewage Disposal. J. B. Lippincott Co.
Jameson. The Flame Fiend. Allyn and Bacon.
Jones and Hartt. Priscilla Book of Fabric Renovation and Spot Removal. Priscilla Publishing Co., Boston.
Lynde. Physics of the Household. The Macmillan Co.
Mason. The Origins of Inventions. Charles Scribner's Sons.
Red Cross First Aid Book. Blakiston and Co.
Simmons. Soap. Isaac Pitman and Sons.
Tyndall. Forms of Water. D. Appleton and Co.
Weeks. The Avoidance of Fires. D. C. Heath and Co.



KEY PICTURE 7. — COMMUNITY WATER SUPPLY.

Above: **A**, mountains; **B**, mountain streams; **C**, reservoir; **D**, dam; **E**, sun's heat; **F**, water main; **G**, city; **H**, service pipes; **I**, sewer mains; **J**, sewage septic tank; **K**, filtration beds; **L**, river.

Below: **a**, standpipe (reservoir); **b**, lake; **c**, pumping station; **d**, water table; **e**, main pipe line; **f**, service pipes. Compare the upper and lower diagrams. How do they differ? Name the two kinds of supply systems here shown.

CHAPTER VII

THE CONTROL OF WATER FOR USE IN THE COMMUNITY

Water its living strength first shows
When obstacles its course oppose.
— *Goethe.*

Did You Ever Ask Yourself How a Great City like New York Gets Its Water Supply?

Do you suppose that the water pressure in any city water system ever varies from time to time? Did you ever wonder how water gets to the top of tall buildings like the Woolworth Building? Did you know that water supply systems have to be constantly guarded? Do you know why? Have you any idea why New York City and Los Angeles went hundreds of miles away to get their water supply? Do you suppose that cities use their water supply for other than drinking and washing purposes? How do you suppose that the city of Niagara Falls uses its water supply? Would you like to know something about dams and how they are used? Why do you hear so much about the saving of our forests now? Do you suppose that there can possibly be any relation between our forests and your supply of drinking water? Think this over. Discuss it with your people at home.

Some Practical Questions:

1. Why do cities (like New York) go to the mountains for their water supply?
2. What is meant by water power or "white coal"?
3. What makes water powerful?

4. Why is it likely that water power will be used in this country more and more each year?

5. Why do you hear so much about the planting of new forests to-day?

Home Problem. — Secure a strong paper bag. Fill it two thirds full of water. Close the end tightly. Note the sides of the bag. Now thrust a knitting needle through the sides of the bag a few inches from the bottom. Note the results. Is there any evidence of water pressure? What caused it?

Field Problem. — Observe a street-sprinkling wagon at its work. Note where and how it is filled. Watch its control while it moves and note how it works. Note especially how the water is sent over the street. Explain the principle upon which the sprinkler works.

1. Where and How Do Towns and Cities Get Their Supply of Water?

157. City Water Supply. — Aside from the individual use of water in a city, there must be a very large amount used for sanitary purposes, for water power, steam engines, washing the streets, fountains, and so on. Besides, where great numbers of people live closely together, there must be protection from fire loss and there must be a proper removal of wastes to protect the lives of the whole community. Individual wells are not permitted in large cities, because the contamination[1] of such wells is easy and epidemics[2] may thus be spread. The city, then, must furnish the water supply.

158. Public Control of Water Supply. — Individuals are naturally careless of the health of the community. "What is everybody's business is nobody's business." People forget that every one has equal rights to health and happiness. It follows, then, that public control of the water supply is the only safe method of protecting the health of every individual in the community. Such care for the people has been well illustrated in the cities of Los Angeles and New York.

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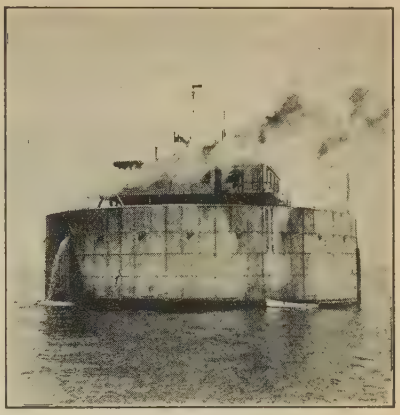
[1] Contamination: making impure or polluting of a substance used as food or drink.

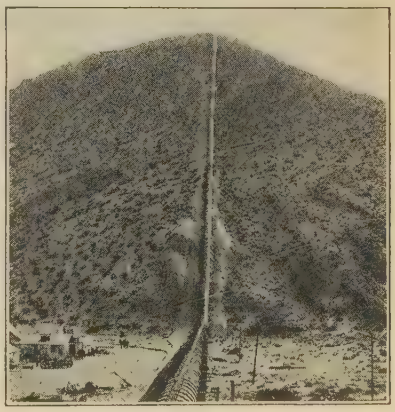
[2] Epidemic: a disease affecting many in a community at once.

Other cities are fast following these excellent examples, and more than 4000 cities now supply their citizens with water from water-supply systems.

159. Conditions and Sources of Water Supply. — The problem of securing good water is closely connected with the location of the city and its natural environment. If the city is on a plain, water must be pumped from streams or artesian wells to a reservoir or stand-pipe. The reservoir is located above the city so that there may be enough fall to carry the water into all the buildings. If the city is in a mountainous region, the problem is simple. Mountain streams are dammed and the supply is usually unlimited. Denver is a city using this method. Still other cities are obliged to purify the water taken from lakes or rivers often full of their own sewage. Buffalo and Cleveland are cities using this method. (Fig. 83.) (Key Picture 7.)



A. Cleveland water supply.



B. Los Angeles aqueduct.

FIGURE 83. — TWO SOURCES AND TWO METHODS OF SECURING A WATER SUPPLY.

A, crib and Lake Erie water for the city of Cleveland. **B**, Los Angeles aqueduct and mountain water.

How is the water secured in each case? Which water source is purer? Why?

160. Typical Water Supply Systems. — Salt Lake City brings its water in deeply laid pipes a distance of more than 40 miles across a desert. The source of this water is the melting snow of the mountains. The water thus formed is collected in reservoirs high up the mountain sides. It is absolutely pure and sufficient. No better tasting water can be found anywhere. (Key Picture 7.)

FIGURE 84. — CONDUIT OF THE NEW YORK CITY WATER SUPPLY SYSTEM.

This brings water 125 miles to the city from the Catskill mountains. Why is the surface smooth?

Los Angeles went 250 miles into the Sierra Nevada mountains where it obtained control of a watershed at an elevation of over 4000 feet. Rains and melting snows supply a river which has been dammed and made into a large lake. From this lake tunnels pierce the mountains and steel conduits cross the deserts carrying enough water to supply the needs of more than 2,000,000 people (Fig. 83). No pumps are necessary. Explain.

The best known and most expensive water system in the world is that of New York City. In 1920 the daily consumption of water was nearly 700,000,000 gallons. Accordingly, the city went more than 125 miles to the Catskill Mountains for a pure and sufficient supply. Removing a railroad and several towns, the city built a dam 4600 feet long and 200 feet high across the lower end of a valley, making a lake 10 miles long, a mile wide, and 192 feet deep, and holding 132,000,000,000 gallons of water at an elevation of 600 feet. This water is brought part way in concrete conduits laid partly under ground. These pipes are 17.5 feet wide and

17 feet high (Fig. 84). At Cornwall the water is carried under the Hudson River by a tunnel 14.5 feet in diameter, cut through solid rock, 1100 feet below the surface of the river. This same water is carried under Manhattan and the East River into Brooklyn and thence to Staten Island in conduits 11 feet in diameter, cut through solid rock 250 feet below the surface of the ground. The total cost of this system exceeded $200,000,000. This supply gives every individual in New York City 100 gallons of water each day. It is extremely pure, is chemically tested every day, and will give a sufficient supply for some years to come.

The recent addition of the head waters of the Schoharie Creek basin and another mighty dam will supply enough water for 10,000,000 people. (Key Picture 7.)

161. Securing Water Pressure. — There are three principal ways of securing a water supply for a city, depending largely upon the location of the city, namely, (1) the simple gravity system, (2) the pumping system, and (3) the gravity and pumping system. But in every system the securing of sufficient water pressure is the important thing, aside from its purity and abundance. Cities situated in flat plains, with no elevation near, have a problem to solve in forcing water to the tops of buildings.

162. How Water Power Is Obtained and Increased. — Your demonstration of water pressure showed you that the weight of the water causes this pressure. How, then, can water pressure be obtained and increased for the use of power and irrigation projects? The answer is: By means of dams. A demonstration will show this in a very simple and clear way.

Demonstration 21: *Problem: How can water pressure be obtained and increased?*

Materials: A gallon varnish or oil can with the top removed; some small pieces of rubber tissue, one inch in diameter; water; an iron tripod; and a shallow dish. (Fig. 85.)

Method: Punch three small holes with a small nail along one side of the can — one hole about one-half inch above the bottom, the

second hole about one-half way to the top, and the third about two inches from the top. Pour into the can some water and as it begins to flow through the lowest hole, place one of the pieces of rubber tissue over it on the inside of the can. Keep filling the can and as the water reaches the second and third holes cover them with pieces of rubber. When the can is filled, remove the top piece of rubber for a moment; now the bottom piece after replacing the top; now the middle one after replacing the bottom one.

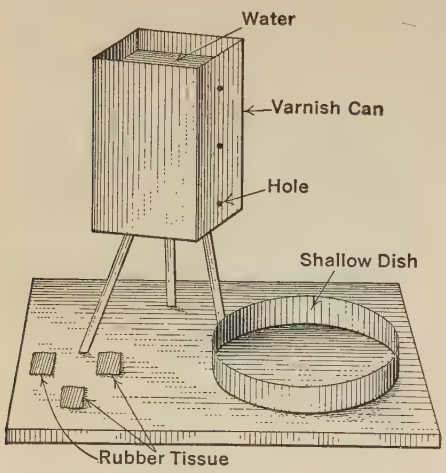


FIGURE 85. — DEMONSTRATION 21.
How a dam increases water pressure. Give the use of each part here labeled.

Observations: What keeps the pieces of rubber in place? What happens when each of the pieces of rubber is removed? Is there any difference between the distances to which the water is thrown and the directions in which the streams are thrown? How can you account for these differences? How is water pressure obtained and increased? What might you compare the front and any two sides of the can with? Explain.

Conclusion: Give your conclusion with proofs.

Practical Applications: Most of the great power dams and water storage dams are of very great height, some over one hundred feet. Why should they be built so high? Their bases (Fig. 86) are very much greater than their tops. What is the reason for this method of construction?

163. Dams. — Large quantities of water are impounded by means of dams, built to stand an enormous pressure of water, even during flood conditions. The foundations must be laid upon bed rock. Why? In some places dams are so built that they are in the form of an arc with convex

side facing the impounded water. What is the advantage of this form? Dams must be built of heavy stone, concrete, and steel. Why? Such dams are well illustrated by the Kensico and Ashokan dams of the New York City water system. The Olin Bridge dam in the Catskills is 119 feet wide at its base, 220 feet high, and 5660 feet long, and holds back 132,000,000,000 gallons of water.

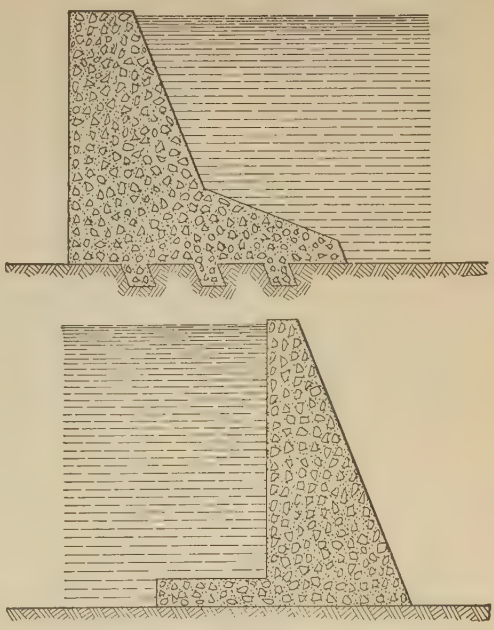


FIGURE 86.—TWO TYPES OF DAMS IN CROSS SECTION.

Do the results of Demonstration 21 help you in understanding this picture? Which is the stronger dam? Why?

Dams enable the water behind them to exert terrific pressure. The tremendous weight of the water behind the dam forces the water through the conduits. At the Olin Bridge dam, the pressure on the whole face of the dam is estimated to be about 8,000,000 pounds.

164. Cause of Unequal Pressure and How Controlled. — The friction of the water flowing through large pipes seriously interferes with the flow and force of the water. Constant use of water, especially at certain times of the day, reduces the pressure greatly. To offset this, dams are built high to give great pressure and in many cases supplementary reser-

voirs are connected with the mains at hours when most water is used, or pumping stations help force it through the pipes. In small cities high standpipes aid in keeping up the pressure. Explain.

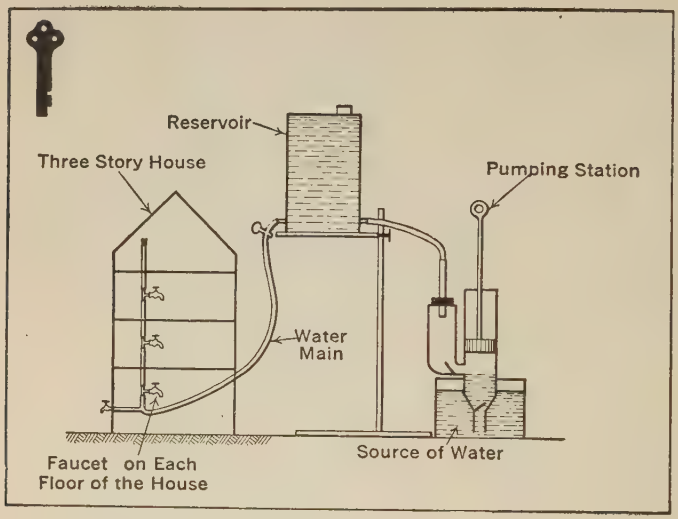


FIGURE 87. — (KEY) DEMONSTRATION 22.

Find out the use of each part of this apparatus. How does it work?

(Key) Demonstration 22: ***Problem: What are the principles of the gravity system and the pumping system of supplying a community with water?***

Materials: Rubber tubing, with a stopper to fit it; glass " T " tubes; pinchcocks representing faucets; glass tubing; a small glass pump; a one-gallon varnish can (without stopper) with two openings, one in one side near the top, and one in the opposite side near the bottom, to which have been soldered short metal tubes; a board representing a house as in Figure 87; a ring stand; and a pan to hold water.

Method: Arrange the apparatus as in Figure 87. Fill the can with water and open the pinchcock just below the can. Note the course of the water in the rubber and glass tubes. Open each pinchcock-faucet, keeping the others closed while one is open. Then open all the pinchcocks together. After the water has run out of

the tank, pump water into it with the glass pump. Connect the "water main" directly with the pump, and pump water through it.

Observations: Why did the water rise in the tubing to different floors of the building? Where was the most force shown? Explain. How could you have increased this force? What is the advantage of the pump? How does it work? Explain. What is the advantage of pumping water directly into the water main? What is the disadvantage? Explain.

Conclusion: Explain fully the principles of the gravity and the pumping systems of supplying water to a community.

Practical Application: How could a city with tall buildings increase the pressure of a gravity system? Would the reservoir have to be closed to make this possible?

2. Why May the Water Supply Be Dangerous?

165. Dangers in the Water Supply. — Now the most important reason for the construction of large and costly water supply systems is the desire to secure an abundance of *pure*

Figure 88. — Some Common Country Water Supply Dangers.
Where are the dangers in this picture? Which farmer (**A** or **B**) will get pure water? Why?

water. Where people live close to each other in large communities, it is impossible to secure water for all without constantly facing the serious danger of epidemics. The use of a great water supply system makes it necessary to exercise the strictest care in selecting the source of the water.

There are many examples of this kind of danger and its terrible results. In Plymouth, Pennsylvania, typhoid germs were carried by melting snow into the city water supply system. Over 1000 cases of the fever and scores of deaths resulted. Read the newspaper item below and see how important the water supply is to our daily lives:

1000 Are Made Ill by Impure Water

The State Department of Health reports that over 1000 persons in an up-state health resort were made ill by the temporary changing of the water supply source by the Water Board without taking precautions to see that this temporary source was pure. This supply was drawn from a lake which is seriously polluted with sewage from several houses and by run-off water from a large part of the village. — *New York Times.*

All such cases prove that danger lurks in city water supplies. Most cities now employ expert chemists (kĕm′ĭsts), who daily analyze (ăn′ȧ-līz) samples of the water supply; when the least indication of contamination appears, the supply is stopped or is chemically treated so that the possibility of an epidemic is prevented.

166. Pure Water. — Without pure water the lives of all persons are in constant danger. Impure water contains disease-producing impurities absorbed from the air or soil. Most of us little think of the extreme care used in protecting water from impurities in the larger towns and cities. You have learned that *boiling* is a good way of making impure water safe. Explain. After standing for some time, the greater part of it can be poured off into clean receptacles to be used as needed. It must be admitted, however, that boiled water is insipid or tasteless, due to the driving out of the air by the heat. The longer it stands in a protected place before being used, the better it will taste. Explain. Again, water may be *distilled*.[1] Simple apparatus for this method of

[1] Distilled: freed from impurities by being vaporized and condensed.

purifying water may be made by anyone. Finally, *filters*[1] can be procured which can be attached to the faucet or other outlet attached to a water receptacle. Sand, cotton, and charcoal are placed in these filters and strain out suspended matter to which bacteria may be attached. Free floating organisms will, however, pass through even these filters. Because these filters soon become full of refuse and are often neglected, they cannot be considered very safe.

3. How Can a Community Water Supply Be Made Safe?

167. Pure Water Protection in the Country. — With the securing of pure water for the home, the problem is just one-half solved. This water must be kept pure. If you depend

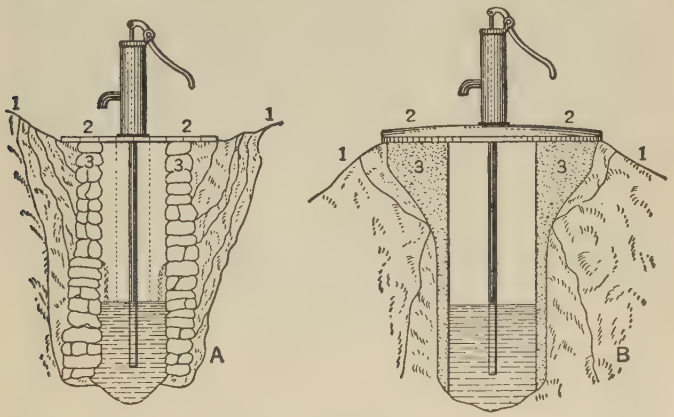


Figure 89. — Good and Poor Well Construction and Conditions.
Compare the parts having similar figures in both pictures. Tell which conditions are right and which are wrong. Give your reasons.

upon a well, it must reach the water table (see page 159). In all cases the proper protection of the well or spring from all possible contaminations is most important (Figs. 88 and 89). Wells and springs should be encased in a water-

[1] Filter: an apparatus which strains out suspended matter from a liquid.

tight cement lining and should be covered to keep out foreign bodies. In all cases the lining should be carried up flush with the well or spring platform, which in turn should always be above the level of the ground and water-tight. Explain. The surface of the ground around the spring or well should slope away from it and should be graveled and kept absolutely free from refuse, garbage, or other foreign matter (Fig. 89). If a spring is piped to the house, it should have a good fall and the pipe should be well secured in the wall of the house.

168. Pure Water Protection in the City. — If you live in a city the Board of Health or the Department of Water Supply is responsible for the purity of the water you use. Besides maintaining the purity of the source, it must constantly watch the water while it is on its way to the city and in the city itself. The sources of the New York City water supply, for example, are at an elevation where very few people live because no agricultural lands are found in the mountains. This is also true of the Los Angeles, Denver, and Salt Lake City water supplies.

At the Ashokan and Kensico reservoirs great aërators continually shoot the water up to great heights (Fig. 90), thus mixing it with the air. This air, together with the sunlight, tends to kill the bacteria in the water and removes any unpleasant tastes and odors. Proof of this aëration process is often noted when water is suddenly drawn in a glass from the faucet. The water looks milky, due to the enormous number of air bubbles in it. These bubbles make the water sweet and palatable.[1] The reservoirs also tend to kill off germs since they serve as huge settling tanks or basins, and allow the sun shining down upon them to kill the germs in the water. Furthermore, chlorine (klō′rĭn) gas, which is a strong sterilizer,[2] is injected into the water near the Kensico dam, whenever the daily examination of the water seems to

[1] Palatable: pleasant to taste.

[2] Sterilizer: a substance which frees another substance from germ life.

require it. Finally, the city owns a 1000-foot marginal strip of land around the whole reservoir. This strip is fenced off and constantly guarded by New York City mounted police. It is these precautions which make the New York City water supply the finest in the world and the city itself absolutely free from epidemics due to water contamination.

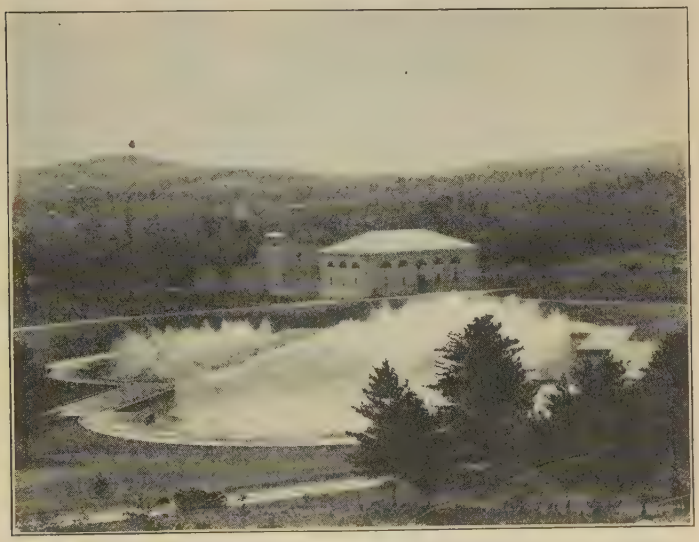


FIGURE 90. — THE ASHOKAN AËRATORS.

This water is filled with oxygen and then sent on to New York City 125 miles away. What is the value of the process?

169. Purification of the Water Supply. — Many cities, as Buffalo, Cleveland, St. Louis, and Chicago, must take their water from rivers and lakes. They must purify this water to make it fit to drink.

By a long series of experiments, Robert Koch, a German bacteriologist, discovered that sand was an excellent water filter. Used in Germany, it at once reduced the number of cases of cholera in Altona, which used the polluted waters of the Elbe River. In 1892 there were 17,000 cases of this

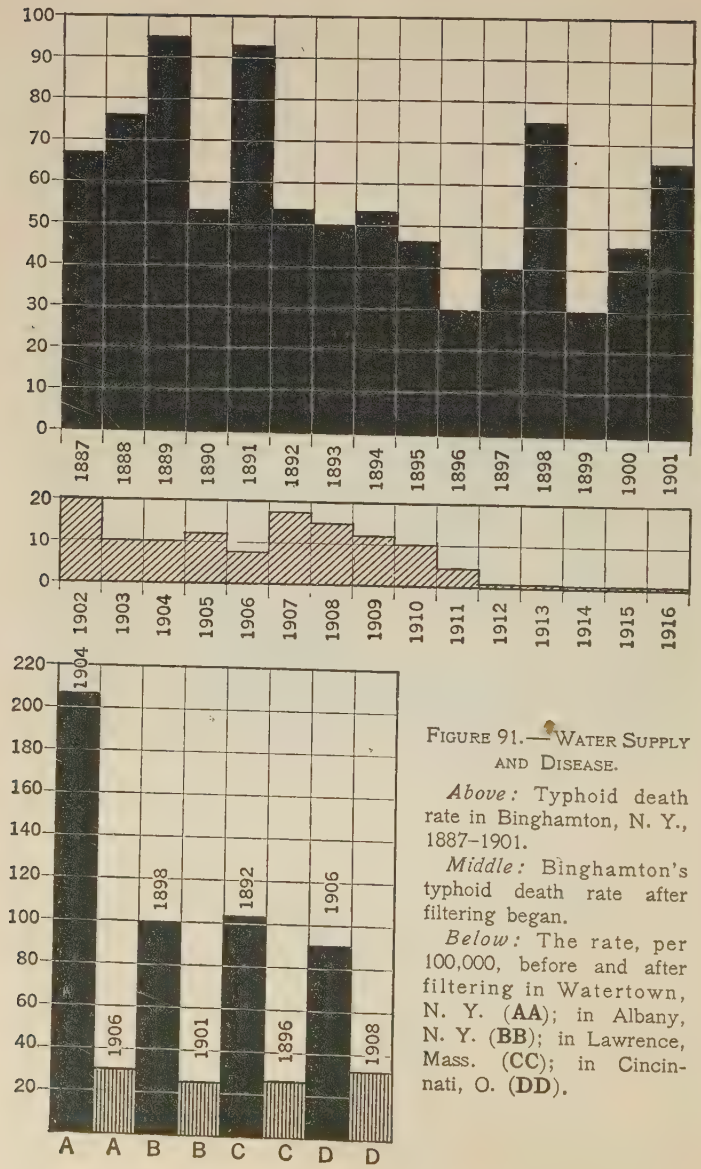


FIGURE 91.—WATER SUPPLY AND DISEASE.

Above: Typhoid death rate in Binghamton, N. Y., 1887–1901.

Middle: Binghamton's typhoid death rate after filtering began.

Below: The rate, per 100,000, before and after filtering in Watertown, N. Y. (**AA**); in Albany, N. Y. (**BB**); in Lawrence, Mass. (**CC**); in Cincinnati, O. (**DD**).

disease in Hamburg, while in Altona there were but a few scattered cases. Altona was free from the epidemic because its water supply was filtered.

Many American cities have long used filters, which often cover acres of land. Wherever filter beds have been installed the death rate has at once dropped. Albany, N. Y., was at one time a noted typhoid center, as it took its water from the Hudson River polluted with the sewage of Troy, Cohoes, and other cities above it. Watertown, N. Y., was once of similar reputation because it secured its water from the Black River, a muddy, dirty stream. Study Figure 91 and explain it fully.

4. How Is Waste Water Taken from the Community?

170. The Problem of Sewage Disposal. — To insure health and freedom from disease, every effort should be made to keep the water supply free from contamination. New York City empties its sewage into New York Bay and while

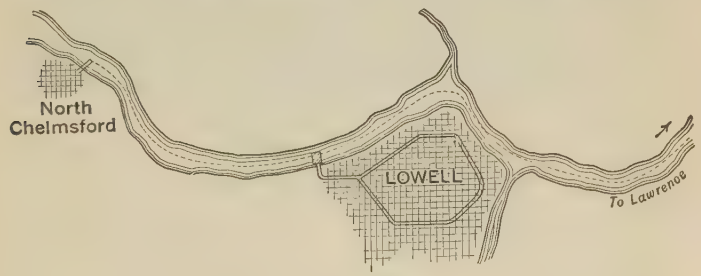


Figure 92. — How Disease Was Spread by Water.

North Chelmsford sent its sewage into the river. Lowell, Mass., took its drinking water from this river. Lawrence, Mass., did the same. Both had epidemics of typhoid fever. Why? What was the remedy?

the danger is much reduced, since the sewage is carried out to sea, yet it is a menace to towns along the coast. Troy, Albany, and Poughkeepsie empty their sewage into the Hudson River, making the waters of this river extremely filthy.

Chicago, Buffalo, and other cities used to empty their sewage into lakes from which they secure their water supply. The death rate finally forced Chicago to build a drainage canal to carry its sewage into the Illinois River. Buffalo now draws its water from "cribs" five miles out in Lake Erie but even so must filter its supply to be on the safe side.

171. Dangers from Sewage. — Water is the natural carrier of sewage or filth. To this filth are attached untold millions of bacteria which are known to cause five different

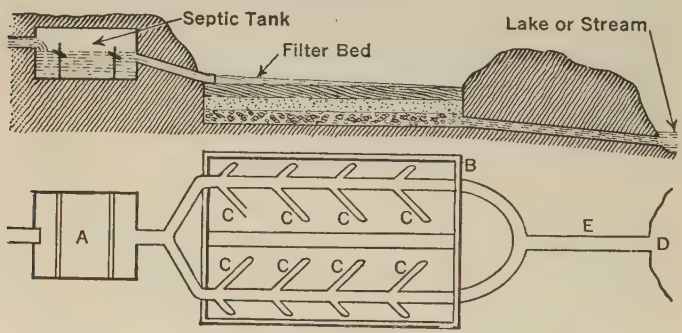


FIGURE 93. — CONTACT FILTER BEDS CONNECTED WITH SEPTIC TANK.

Study again Figure 77 and see its connection with this picture. Note the layers of sand, gravel, etc. At **C** the sewage is widely distributed, seeping down through the filter bed and then out through **E** and into **D** in a clear, pure condition. What cleans this sewage water?

diseases — cholera, typhoid fever, dysentery, diarrhea, and enteritis. These diseases can be contracted by drinking water polluted with sewage (Fig. 83).

172. Sewage Disposal Plants. — Most communities situated on flat areas now use sewage disposal plants, of which there are several types. (1) The septic tank and underdrain is effective for small cities. The tank consists of several compartments generally made of concrete and set deep in the ground. The sewage is run into one end of this tank where it begins to be decomposed by *anaërobic*[1] (ăn-

[1] Anaërobic bacteria are those that live where air is absent.

ā′ĕr-ŏb′ĭk) bacteria. They cause the sewage to become almost completely liquefied. Fats rise to the top, forming a scum which cuts off all air, making the conditions still better for these bacteria which thrive best without oxygen (Figs. 77 and 93). The sludge, or solid contents of the tank, must be cleaned out at regular intervals. This sludge is very valuable as a soil fertilizer.[1] (2) Contact filter beds are used where a very large amount of sewage must be disposed of.

FIGURE 94. — A MODERN STREET VACUUM CLEANER.

Note the brushes. These loosen the dirt. A powerful vacuum pump does the rest. Where does the dirt go? Explain.

173. Community Street Cleaning. — A Department of Street Cleaning is the only solution of the street cleaning problem in a large city. Enormous quantities of water poured into the streets from the hydrants and through hose lines make the work of street cleaners effective. Some cities are models in this respect, especially San Diego and Salt Lake City. Some even use enormous motor-driven vacuum cleaners, which prevent the scattering of dust and disease germs (Fig. 94).

[1] Soil fertilizer: soil enricher.

More than 5,000,000 tons of dust and rubbish are disposed of each year in New York City. Garbage is collected daily by another group of men, is burned in special incinerating plants, its fats having been removed by chemicals for soap and perfumes, and its ashes used as fertilizers. Rubbish is collected by still another set of men and is sorted; part is destroyed and part is made into paper, cloth, tinware, and fertilizers.

FIGURE 95. — A TYPICAL FOREST FLOOR.

A thick carpet of dead leaves and mold. This keeps in the moisture. This woodlot is carefully tended by the owner.

5. WHAT HAVE FORESTS TO DO WITH YOUR WATER SUPPLY?

174. Forests and Community Water Supply. — Sewage disposal depends upon an adequate water supply and an *adequate water supply depends upon adequate forests.* How can this be? Forest trees hold twice as much water in the soil as open ground covered by grass and bushes. Their

shade prevents excessive evaporation of water from the soil on hot summer days. Their roots hold the soil firmly together and this soil holds much water. The dead leaves as they fall each year form a mulch or covering on the forest floor which helps to keep the water in the soil (Fig. 95).

U. S. Forest Service.

FIGURE 96. — AFTER A FOREST FIRE.

Give some of the causes of such fires. Give some of their effects. How can they be prevented?

The net result of these things is that water is allowed to flow gradually and steadily from the hills and mountains into the valleys and community water supply systems. When forest areas are cut off, during part of the year there is little or no water flowing in the streams, especially during dry periods in the summer. At other times, during spring or after heavy rains, raging torrents pass down dry stream beds and cause immense loss of property and life.

How long would New York City enjoy adequate water supply if the Catskill and Adirondack mountains were denuded of their forests?

On the other hand, cities on the Ohio River such as Cincinnati, and Pittsburgh on the Allegheny and Monongahela rivers are yearly subjected to destructive floods due in part at least to the cutting off of the forests in western Pennsylvania. These cities are now spending millions of dollars in an effort to replant these cut-over areas with new trees, hoping that these tremendous losses may be stopped for all time.

FIGURE 97A. — A FIRE RANGER'S WATCH TOWER IN THE CATSKILL MOUNTAINS.

From this tower, about 75 feet high, a good view is obtained of the forests and forest fires. How are these towers of value?

175. Forest Protection. — The necessity for forest protection is plain. Many communities now own the forest areas controlling their water supply areas. Many states such as New York, Pennsylvania, Vermont, and others have set aside large areas of forest lands as state reserves. Numerous states have founded colleges of forestry where young men may learn to become foresters, trained to care for forests and to superintend their proper cutting, thinning, their protection from fires, insects, and disease, and their proper planting (Figs. 97–100).

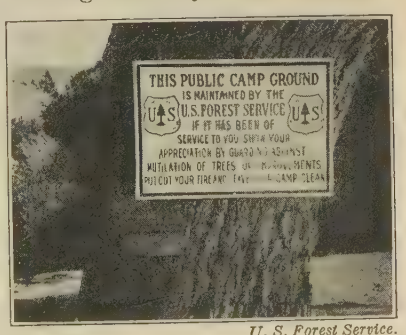
U. S. Forest Service.

FIGURE 97B. — LOCATING A FIRE.

Forest ranger locating a fire by map and alidade (a measuring instrument) in Striped Peak Lookout Station, Idaho.

The Federal government has set aside 16 national parks, most of which are sources for large river systems, thus protecting the water supply of large areas of the country for all time.

To check further this increase of floods and to insure plenty of water power and water supply for future generations, the United States government is now reforesting many water sources, especially in the Rocky and Sierra Nevada mountains in the West



U. S. Forest Service.

FIGURE 98. — HOW YOU CAN HELP SAVE OUR FORESTS.

Fire sign on tree in Inyo National Forest, Colorado.

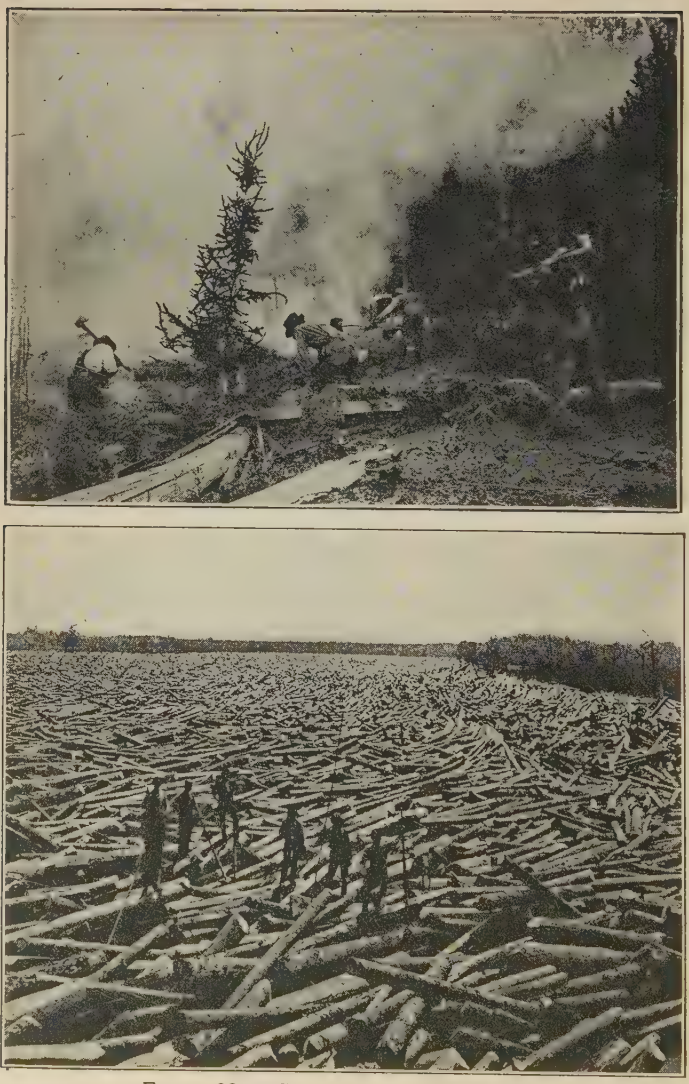


FIGURE 99. — SOURCES OF DEFORESTATION.

Above: The forests' worst enemy making an attack.
Below: Under what conditions is such deforestation permissible?

and in the White and Appalachian mountains in the East. One of the kinds of work to-day is the providing for the future just as the past generations have provided for us. To look out only for ourselves during our own lifetime is selfish and shortsighted. It should be your endeavor as a future citizen of this great country to help in every possible way in the work of forest conservation.

U. S. Forest Service.

FIGURE 100. — PLANTING A NEW FOREST.

Crew setting out seedlings in San Jose National Forest, Idaho.

176. The Relation between Cause and Effect. — To see relations between the factors of your environment gives your mind continual exercise and satisfaction. You already know that every cause has its effect; every effect its cause. Let us see briefly how causes and effects are related in the chapter just studied.

Water is raised from the earth as water vapor by the sun's heat. It falls as rain sooner or later. Its weight carries it down the hillsides; it forms streams which may turn

water wheels and machinery or supply a large city with water for many purposes. In every case work is done. In short, the sun runs our factories and furnishes us our drinking water. The sun's heat raises the water and through

U. S. Forest Service.

FIGURE 101. — A NEW FOREST PLANTED.

White pine plantation, Natural Bridge National Forest, Virginia.

the water it is transformed into motion which does work for us. You will be called upon many times during your study of science to trace the causal relations in the *transformation*[1] *of energy*, for this is the way the work of the world is done and you should become fully familiar with the process.

REVIEW OUTLINE

1. The Community Water Supply System.
   - Relation to water weight and pressure.
   - Need of its public control.
   - Sources and conditions determining water supply.
   - Typical water supply systems (Los Angeles and New York).

[1] Transformation: a change of form.

2. Methods of Securing Water Pressure.
   By going to high elevations for the water.
   By pumping water to tall standpipes or reservoirs.
   By building high dams.
3. Causes of unequal water pressure.
4. Dangers in Community Water Supply.
5. Methods of Securing a Pure Water Supply.
   Selection of pure sources.
   Protection of supply.
   Purification of supply.
      Methods of purification.
6. The Problem of Sewage Disposal.
   Dangers from sewage.
   Types of sewage disposal plants.
7. Community Street Cleaning.
   Relation to water supply and sewage disposal.
8. Relation of Forests to Water Power and the Community Water Supply.
   Need and importance of forest conservation.
   Methods used to protect the forests.
9. Relation of Cause and Effect.
   Water supply and water power due to the work of the sun.

SUMMARY

Water exerts pressure because of its *weight.* Water will thus readily flow down hill or even up hill through a *siphon,* provided the place to which it is flowing is lower than its source. This characteristic of water makes possible various types of *community water supply systems* which are essential to the health and well-being of the inhabitants of large towns and cities.

The most common forms or types of water supply systems are the *gravity system* (New York and Los Angeles) and the *pumping system* (Buffalo and Cleveland). In all systems there is a constant danger of *pollution.* This calls for careful selection of *sources, constant purification,* and *watchful guarding* of the *sources* and *conduits.*

Connected directly with the water supply is the *sewage system.* The dangers from sewage are great and the most approved method of handling it is by specially constructed *sewage disposal* plants. A surface problem is that of *street cleaning,* which means the removal of dirt containing *disease germs.* The most approved method is to *flush* filth into the sewers by water from the water supply system.

Provided there is sufficient water to use, dams are built to increase water pressure.

Finally, regularity of *water supply* and *water power* depends on the *forests*. Forests conserve and regulate the water supply. With abundant forests, constant water supply is assured forever. Our forests must be conserved and protected at all costs. This relation between our water supply and the forests well illustrates the law of cause and effect.

The sun gives us water to drink and to run our factories. Energy is transformed from the sun to the spinning wheel or lathe, and because of this transformation man can make the factors of his environment work together for his own good.

REMEMBER THAT —

It is well for you to keep in mind the big points of each chapter by going over the Review Outline, checking the Key Words, and reading the Summary. Then you are ready for the Thought Questions and Special Problems.

These "Remember That —" statements, if memorized, will make it easier for you to solve new problems which are connected with the work already completed.

Try to use these statements for your own good. Moreover, see if you cannot find some important thing in each chapter which the author has overlooked and add it to the list. This is one good way of becoming a real scientist.

Remember that :

1. Water exerts pressure upon all surfaces because of its great weight.
2. Pure water can be carried long distances and be supplied to communities because of its weight.
3. Water is important in the disposal of wastes known as sewage.
4. Water when impounded behind dams has great capacity for doing work.
5. The conservation of our forests is the only sure method of insuring a sufficient water supply for the future.

THOUGHT QUESTIONS

1. Bubbles of air as they pass upward through water get larger very rapidly. Explain.

2. The water pressure in any city water supply system is greatest at about 3 A.M. Explain this.

3. What are the principal sources of pollution of the streams near your community? Do you think this pollution necessary? Explain.

4. Why should all homes be required to connect up with the sewer system of a community, if one is provided?

5. What is the principle of the sand filter?

6. Why is a septic tank better than a cesspool?

7. Give at least five arguments for the conservation of forests.

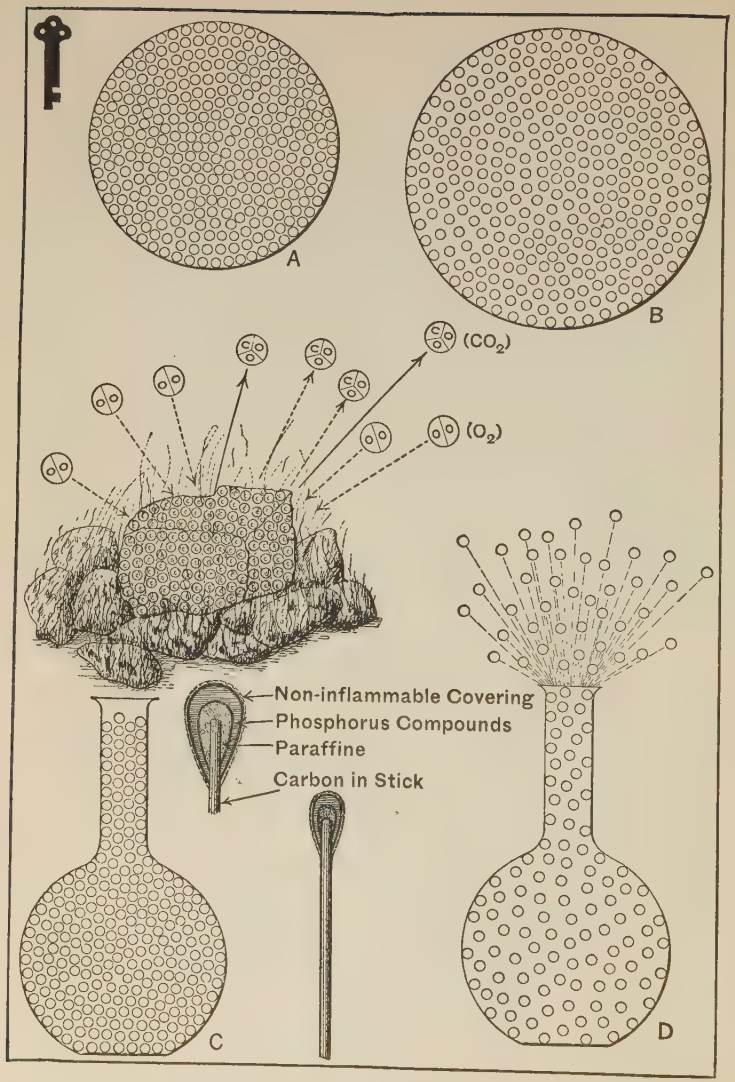
8. Name five ways in which you might coöperate in keeping the streets of your community clean.

9. What is the advantage of storing city water in still water reservoirs?

10. Account for the fact that Cleveland, Chicago, and Buffalo get their water supply from lakes. Why do they go far out into these lakes for the source of their water?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Blount. Health, Public and Personal. Allyn and Bacon.
Clyde. A Drop of Water. Chemical Publishing Co.
Fish and Fisher. How to Live. Funk and Wagnalls Co.
Green. Principles of American Forestry. Wiley.
Hazen. Clean Water and How to Get It. Wiley.
Richards. Sanitation in Daily Life. Whitcomb.
Rossiter. Romance of a Living Temple. Sully.
Roth. First Book of Forestry. Ginn and Co.
Winslow. Healthy Living. Charles E. Merrill Co.
Catskill Water Supply System. Department of Water Supply, Gas and Electricity. New York City.



KEY PICTURE 8. — HEAT AND MATTER.

A, an iron ball; **B**, the ball after being heated; **C**, a flask of water; **D**, the water after being heated. Note the order of layers in the match. What goes into a fire? What comes out? What element is common to most fuels?

CHAPTER VIII

THE SOURCES AND CONTROL OF HEAT

Heat with viewless fingers moulds,
Swells and mellows and matures,
Paints and flavors and allures,
Bird and brier inly warms,
Still enriches and transforms,
Gives the reed and lily length,
Adds to oak and oxen strength,
Transforming what it doth infold,
Life out of death, new out of old. — *Emerson.*

What Do You Mean When You Say a Thing Is Hot?

What do you think heat is? Do you have any idea where heat comes from? Do you suppose that heat ever has any effect upon matter? What is the most common way of producing heat in your own home? Would you like to know some of the methods by which heat is produced and controlled? Did you ever think of the real use of a thermometer in your home? The distribution of heat in buildings is a real problem. Did you ever think of it as a problem? Have you ever heard or known of some of the dangers of heat in a home? You have already learned that heat can do work. Would you like to know of some of the many ways in which men make it do work?

Some Practical Questions:

1. If a piece of metal is pounded, it gets hot. Explain.
2. Why does a fireplace often smoke when a fire is built in it?
3. Coal was first called "black rock." Why does it burn and why cannot ordinary rock be made to burn?

4. Kerosene and gasoline are both fuels. Why is one more dangerous than the other?

5. Why is the upper part of a room always warmer than the lower part?

Home Problems. — 1. Hold the bulb of a thermometer for a few seconds between the fingers and thumb and note the column of mercury. Account for its action.

2. Place the thermometer in the direct rays of the sun for some time, read the scale, and then place in the refrigerator. Explain the difference in the readings.

3. Hold the thermometer over the top of the stove, read the scale, and then place in the part of the room farthest away from the stove. Compare readings. Account for the differences.

4. Give all the sources of heat you can and determine which can give the most even and steady heat during 24 hours.

Field Problems. — 1. On the way to school note all the things you see done through the influence or power of heat.

2. Observe all possible ways in which heat is used by men in 24 hours.

1. What Heat Is and How It Is Produced

177. Our Dependence upon Heat. — To realize the importance of heat, you need only to think of what conditions would be without it. The earth would be a solid mass of stone and ice. No life could exist upon its surface. But, fortunately, the life-giving heat of summer makes possible the growing of plants and the reaping of bountiful harvests. The burning of fuels in the home and factory makes possible our comfort, our work, and the manufacture of useful things.

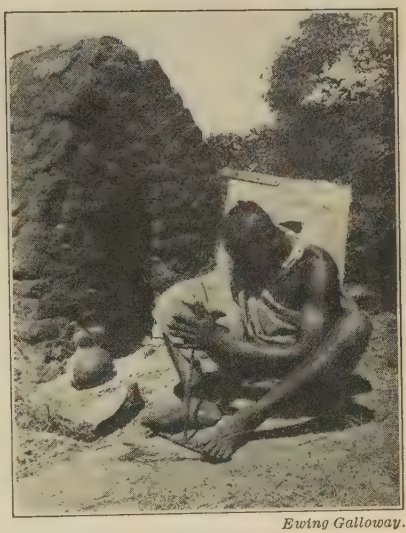
178. What Is Heat? — This is a question which can be answered by working an easy experiment.

Suggested Experiment. — Secure a block of metal, a platform balance, a pair of pliers, a Bunsen burner, a Florence flask with a toy balloon attached to its mouth. Place the metal block on one platform of the scales and balance it. Now remove the block and heat it for five minutes in the Bunsen flame. Place it again on the platform of the balance. Is it lighter than before? Is it heavier than before? Is heat matter? Give reasons for your answer.

Now apply the Bunsen flame to one side of the flask. What happens to the balloon? Account for this action. Does the heat

do work? What did the work in the flask? Is there transformation of energy here? Explain. How was the heat produced? If heat is not matter and does work, what is it?

179. Sources of Heat. — If you set the flask with the toy balloon attached to its mouth in the direct rays of the sun, in a few moments the balloon will become inflated and stand erect. The sun is evidently a source of heat. Explain. A second source is that found in chemical action. A little sulphuric acid poured upon a small amount of water or upon a little zinc in a test tube will produce much heat, but no flames will appear. A third source is electrical energy. The heat given off from an electric light bulb is familiar to you. The electric heater, the electric toaster, curling iron, and electric pad are common examples of heat sources. A fourth and most common source of heat which can be controlled or regulated is found in the chemical process of burning wood, coal, gas, or other substances containing the same fuel elements. Without this means of releasing heat our present advanced civilization would probably have been much delayed. (Key Picture 8.)



Ewing Galloway.

FIGURE 102. — PRODUCING FIRE BY FRICTION IN WOOD.

One stick is rapidly revolved against another. What must be used to catch the spark?

180. Methods of Producing Fire. — To start a fire the pioneer was obliged to strike flint and steel together, producing a spark which ignited some dry, gauze-like material

called tinder. From this tinder a candle was lighted and from the candle the fire was lighted.

To-day we start a fire easily by the use of a match which is constructed on the principle that different substances ignite at different temperatures. Explain. The phosphorus match, however, has been the cause of unnumbered deaths and the destruction of millions of dollars' worth of property every year in this country. It is estimated that in this country above 500,000 tiny flames are started with matches every minute in the day. Every flame may mean a serious fire. To counteract this danger, the *safety match* has now come into common use and the fire losses from this source are being gradually reduced. Explain the safety match. Give several possible causes of the accidental igniting of matches and the setting of fires. (Key Picture 8.)

2. How Heat Acts upon Matter

(Key) **Demonstration 23:** ***Problem: What effect does heat have upon liquids, gases, and solids?***

Materials: A flask, a, fitted with glass tube and one-holed stopper as in Figure 103; a piece of wood with iron strap fastened to it, b; a flask, c, with toy balloon attached, as in the previous experiment; a Bunsen Burner; an iron ring stand; and a copper strip.

Method: A. Fill flask a with water and insert the cork and tube so that water is forced halfway up the tube. Heat the bottom of the flask with the flame and watch the water in the tube.

B. Hold the iron strap over the flame for a few moments. Note result. Replace iron strap by copper strip. Heat. Note result.

C. Treat flask c with heat as in the previous experiment. Note what happens to the balloon.

Observations: What caused the water to rise in the tube? Was there any more or any less water in the tube after applying the heat? How could this water occupy more space? Was the iron longer after heating than before? Did the copper lengthen still more? Was there more air in the balloon after heating than before? Explain.

Conclusion: What is the effect of heat upon matter?

Practical Applications: Explain why heated air circulates in a room. Why must an expansion tank be used in a hot-water heating system? Why is a space left between the ends of rails in a track? Why are automobile pistons never made of copper?

181. Heat and Molecular Action. — Scientists now know that all matter is made up of invisible particles called *molecules* (mŏl'ĕ-kūlz). We do not know the shape of the particles of matter or the extent of the spaces between them, but if we could imagine them enormously magnified they might be supposed (for the sake of illustration) to look something

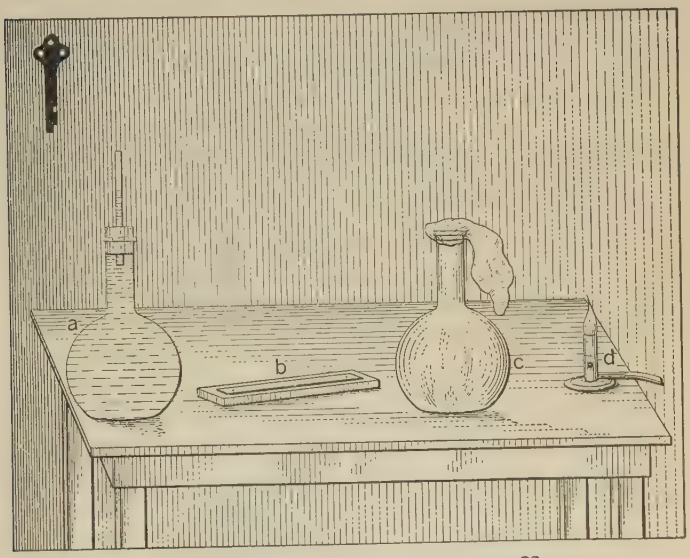


FIGURE 103. — (KEY) DEMONSTRATION 23.

Give the function or use in the demonstration of each part labeled.

like the objects seen in Key Picture 8, **A** and **B**. Each particle we shall call a molecule of iron (Fe). It is now fairly easy to see how the whole mass of iron can expand or increase in size, if we understand that heat makes the molecules move away from each other. By this movement the spaces between the molecules are increased and we say that the substance expands. Really, nothing gets larger. The substance simply occupies more space now because all the particles composing it are farther apart. What do you suppose

happens to these molecules when iron melts and runs? What happens when water is turned to steam? (Key Picture 8.)

3. How Heat Is Released from Fuels

182. Early Heating of Homes. — The Romans heated their houses by means of a *hypocaust,* consisting of small rooms under the house in which fires were built and which were connected by clay conduits to the rooms above (Fig. 104). The early English homes had a hole in the roof and the fire in the center of the floor (Fig. 105). Finally someone thought of building a chimney at one end of the room and placing the fire at the lower end of it (Fig. 106). How was this method of heating a great improvement? This chimney was enlarged to a fireplace and came down to our forefathers with little change (Figs. 107a and 107b).

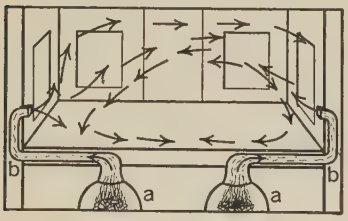


Figure 104. — The Roman Hypocaust.

What is the function of a and of b? Explain the direction of the arrows. Why was this system a poor one?

The first stoves were used in this country about 50 years before the Revolutionary War. In 1742, Benjamin Franklin invented a stove called the "Pennsylvania Fireplace" (Fig. 107c). This was a marked improvement over all preceding heating devices and made Franklin one of the greatest benefactors of mankind. For the first time in history the living room and some adjoining rooms of a home could be

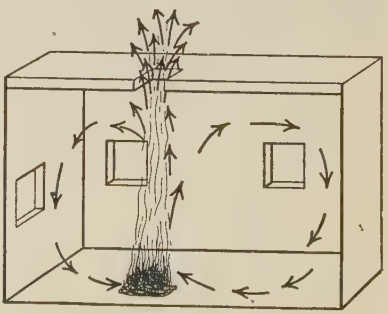


Figure 105. — The Early English Heating System.

Explain the direction of the arrows. Was ventilation insured? Explain. Was this a good heating system?

heated so that they were fairly comfortable in winter. Between 1825 and 1835 the first stoves for the burning of hard coal were invented. From that day to this the principle of heating a home has been fundamentally the same, but the improvements have been marked and numerous. But what makes it possible for us to get heat from certain substances and none from others?

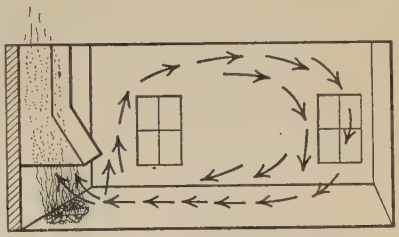


FIGURE 106. — LATER HEATING SYSTEM.

What was the advantage of this system over that shown in Figure 105? Explain.

183. Heat from Oxidation of Fuels. — It is found that only certain substances will oxidize with a steady, continuous

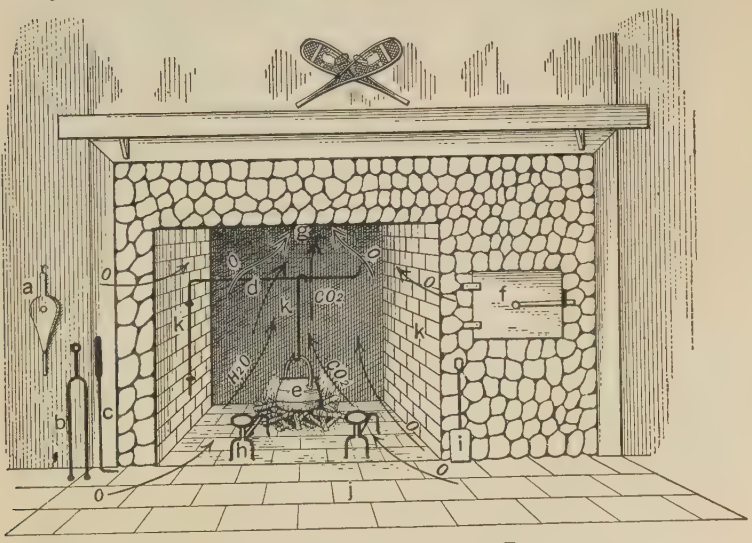


FIGURE 107A, — AN OLD-FASHIONED FIREPLACE.

a, bellows; **b**, tongs; **c**, poker; **d**, crane; **e**, pot; **f**, oven; **g**, flue; **h**, andirons; **i**, shovel; **j**, hearth; **k**, firebrick sides and back; **O**, oxygen; H_2O, water; CO_2, carbon dioxide.

Tell the use of each part and explain the presence of O, H_2O, and CO_2.

flame and with even heat. Iron, glass, granite, and similar materials will not so oxidize under ordinary temperature — some of them will not burn in any temperature, no matter how high. All fuels in order to burn readily must possess the fuel elements — *carbon* and *hydrogen*. Either one or the other or both are always present in hard and soft coal, wood, peat, coke, kerosene, charcoal, gasoline, tallow, etc. For this reason carbon is sometimes called the *central* element of the universe.

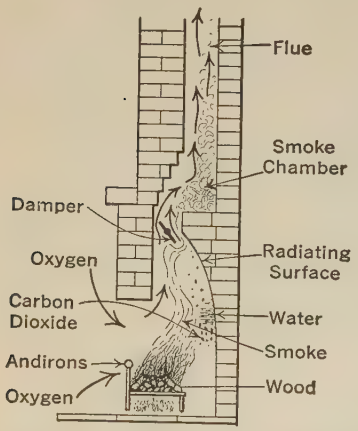


FIGURE 107B. — THE FIREPLACE IN CROSS SECTION.

What is the use of the damper? the smoke chamber? Why is the back of the fireplace curved?

184. What is a Fuel? — *A fuel is any substance which contains the fuel elements and burns readily, producing a large amount of heat at a relatively low cost.* Wood was used almost exclusively as a fuel from the dawn of history down to the year 1820. When heated to a certain temperature, it gives off a gas, which burns readily. It is the burning of this gas which produces the flame and intense heat. Wood comes from trees, which were once alive and composed of parts called organs. Strange to say, coal, kerosene, peat, and gasoline are all fuels having an organic origin — that is, they were all at one time a part of some living thing, either plant or animal.

Charcoal made by the destructive distillation[1] of wood burns without a flame and gives very intense heat. In what

[1] Destructive distillation: driving off of gases from solids by heat in an air-tight retort.

ways is charcoal used to-day? Coal burns slowly and, of all fuels, requires the least care. For this reason coal fires can be kept over night, warming the house evenly. Such fires will burn for long periods of time with reasonable care and are often never extinguished during a whole year.

185. Classes of Fuels. — Fuels may be classified roughly into solids, liquids, and gases. All three forms are now used in the home to prepare foods, to heat water, and to warm the home. Coal as a solid fuel is important because of its great heat value and its comparative safety. It may be classified into soft or bituminous (bĭ-tū′mĭ-nŭs) and hard or anthracite (ăn′thrȧ-sīt). The soft coal is used mostly on railroads and in factories; the hard coal in heating homes, although, due to strikes, people are fast learning how to use soft coal in the home. What are its drawbacks? Kerosene and gasoline are produced by refining the petroleum nearly always found near coal beds. Petroleum results from the slow decomposition of vegetable and animal matter. Coal gas is made by distilling soft coal in air-tight retorts. Much carbon is found in this gas, which accounts for its burning with a luminous flame.

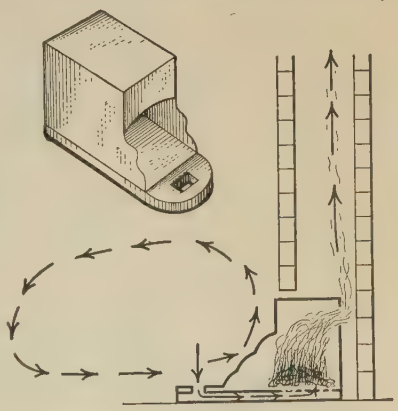


FIGURE 107c. — THE PENNSYLVANIA FIREPLACE.

This was a real stove. Note the draft hole in front. Why was this better than the open fireplace?

186. Heat Values of Fuels. — The unit for determining the heat value of any given amount of fuel is called the *Calorie* (kăl′ō-rĭ), which is the amount of heat required to raise one kilogram of water 1° Centigrade. Sometimes the *British*

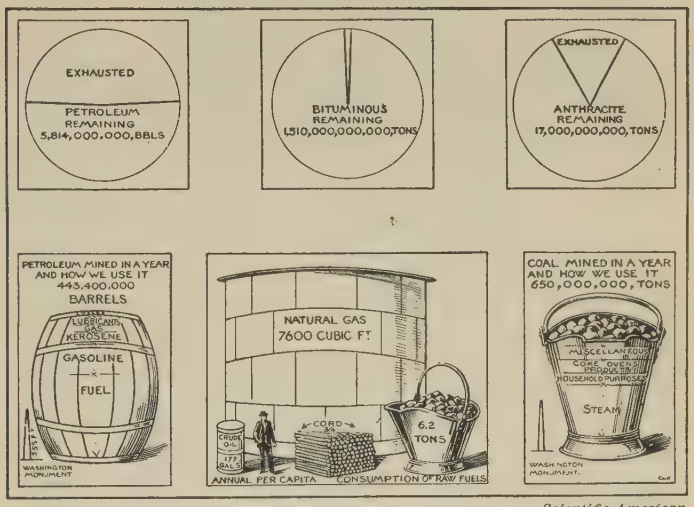
thermal unit (B. T. U.) is used; it is the amount of heat needed to raise one pound of water 1° F. The heat value of any fuel is measured by the use of the *calorimeter* (kăl′ō-rĭm′ē-tēr). The rise in temperature is determined by a thermometer. The heat values of several fuels are given below.

	Calories per Pound	British Thermal Units per Pound
Carbon	3,672	14,544
Hydrogen	15,664	62,932
Wood, Oak	2,100	8,316
Charcoal	3,227	12,780
Peat	1,800 to 2,300	7,200 to 9,000
Coal, Soft	3,000 to 3,600	11,700 to 14,400
Coal, Hard	3,400 to 3,700	13,500 to 15,300
Petroleum	about 5,000	about 20,000

It can be seen from this why hard coal is in such favor among us. But how long will the supply of coal last?

187. Coal Production and Supply. — In 1820, 365 tons of coal were mined in the United States. In 1920 about 1,000,000,000 were mined. Much waste occurs in the mining of coal, actually only about 40% of the coal being used. At the present rate of mining coal, it is estimated that in about the year 2030, or in 110 years, our anthracite coal supply will be exhausted (Fig. 108). Of course, there are untold masses of it in Alaska, Siberia, and in other remote places, but the cost of mining and transporting may make its use almost prohibitive. For the present, fuel oil is rapidly coming into general favor. Special apparatus for the vaporizing and oxidation of fuel oils is now manufactured; it can be attached to any make of furnace. An even and intense heat automatically controlled is developed in these oil burners. They are clean and efficient. How they work can be learned by a careful study of Figures 109a and 109b.

Gas has recently won favor as a furnace fuel. A series of gas jets displace the furnace grate and their operation is automatically controlled by a thermostat. This method provides an even heat and is simple and clean in operation.



Scientific American.

FIGURE 108. — OUR COAL AND OIL RESOURCES.

How much coal and oil have we used? How much have we left?

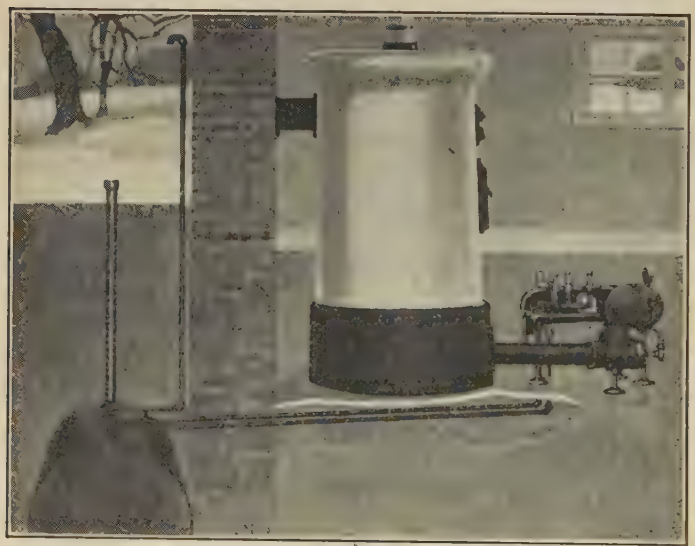
4. HOW HEAT IS USED AND CONTROLLED IN THE HOME

Demonstration 24: *Problem: How is a stove built to burn fuel? Materials:* A Bunsen burner.

Method: Light the Bunsen burner, allowing the smallest supply of gas that will produce a flame to enter. Turn on more gas. Note the effect upon the flame. Close the vent in the burner. Note the effect upon the flame. Open the vent in the burner. Note the effect upon the flame.

Observations: How can you increase the size of the flame? When do you get the most light with your flame? the least light? When do you get the least heat? the most heat? Can you explain the use of the vent? Why does the flame burn with the most heat when the most air is allowed to enter? The air simply pushes the fuel elements apart so that the oxygen can reach them. What do

you suppose causes the luminosity[1] (lū′mĭ-nŏs′ĭ-tĭ) of the flame? You can probably prove this by testing the flame when luminous and non-luminous with a piece of heavy white cardboard. When do you get the most carbon deposit? What does this mean? Now find, in Figures 110b, 112a, and 112b, structures corresponding to the vent in the burner. In the gas or coal stove in your home,



The May Oil Burner Co.

FIGURE 109A. — A MODERN OIL BURNER.

Note the location of the tank. Explain. The machine in front of the furnace vaporizes the oil, and blows it into the fire-box where it is oxidized by an electric spark. The heat is intense. Why? What are the advantages of this method of heating? Has it any disadvantages? Explain.

how is the flame controlled? How are stoves built to control it? How is the coal stove built to conserve the heat? How are the wastes removed? How are the dangerous gases eliminated?

Conclusion: How is the stove in your home built to burn fuel properly? Can you suggest any improvements? Write up in full in your Science Discovery Book.

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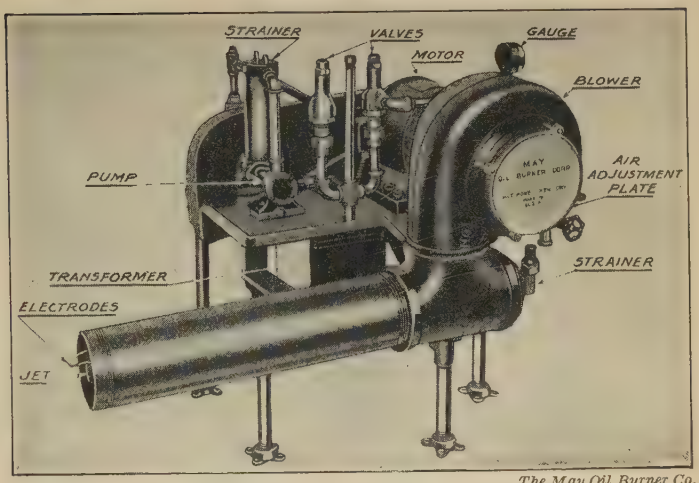
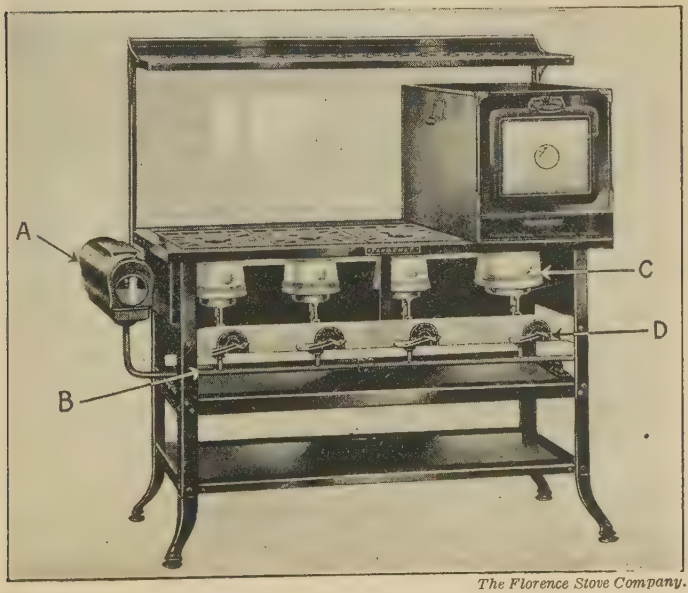
[1] Luminosity: light-giving power.



The May Oil Burner Co.

FIGURE 109B. — PARTS OF THE OIL BURNER.



The Florence Stove Company.

FIGURE 109C. — THE KEROSENE STOVE.

188. The Modern Stove. — The first cook stoves were used in the United States. In 1835 the Stanley rotary stove was first made (Fig. 111a). Then followed the Yankee cook stove (Fig. 111b). The modern cook stove in which wood or coal can be burned differs from all stoves preceding it in that its oven is directly behind the fire pot and is surrounded on three sides by what is called a *diving* flue. In an attempt to use the old and the new together the *range* was invented, so arranged that it might be used in connection with the old fireplace. Now it is used where space must be economized, generally with but one oven door placed on the outside (Fig. 112b). The round stove used for heating country homes is shown in Figure 112a.

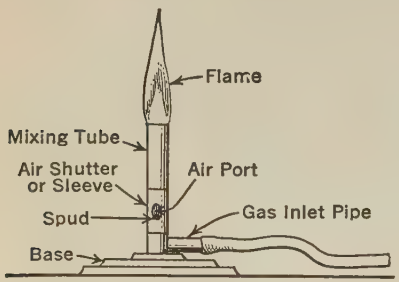


FIGURE 110A. — DEMONSTRATION 24. A BUNSEN BURNER.

In many homes a kerosene stove is used for the family cooking and heating. Figure 109c shows its essential parts. Its principle is similar to that of the Rochester burner lamp (Figure 140, page 272) except that in the burners pictured here there is no real wick, a circular piece of asbestos taking its place. By turning the handles (D) the burners (C) are lowered or lifted either below the oil level in the tank (A) or above it. When below, the oil rises through the burner (in seeking its own level) by means of the feed pipes (B) and soaks through the asbestos. It is then lighted and gives an intense heat for cooking or heating. When raised, the burner goes above the oil level and the flame gradually dies out for lack of oil. The oil is fed gradually into the pipes from the tank by means of a valve.

Gasoline stoves, with a high factor of safety and operating on much the same principle, have recently come into favor.

Then, too, gas stoves are now on the market supplied with gas, under pressure, from portable tanks, brought to the house and connected with a feed pipe line.

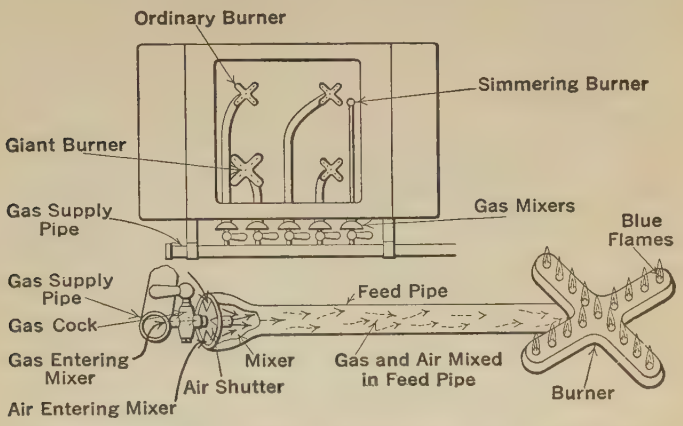


FIGURE 110B. — A GAS STOVE (TOP ABOVE AND ONE BURNER BELOW).

Compare this picture with Figure 110a. Show their likenesses and differences. Explain the use of all parts here.

189. Heat from Electricity. — How and why does an electric current give off heat? You can solve this problem without help from anyone.

Suggested Experiment. — Assemble two dry-cell batteries, some insulated copper wire for connections, an electric button or key and some fine iron wire (No. 28). Connect the dry cells with the large wire so as to make a complete circuit. Connect in the switch. Now complete the circuit by pressing the button or key. How does this affect the wire? Detach the large wire and attach fine wire across two terminals. Close the circuit and watch this fine wire. What happens? What made the difference? Upon what does the amount of heat given off

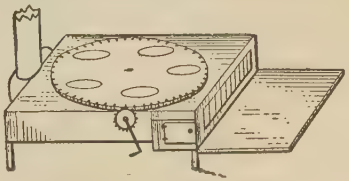


FIGURE 111A. — A STANLEY ROTARY STOVE.

How was this an improvement over the Pennsylvania fireplace? Why is this a poor stove?

seem to depend? What do you think causes an electric current to give off heat while passing through a wire?

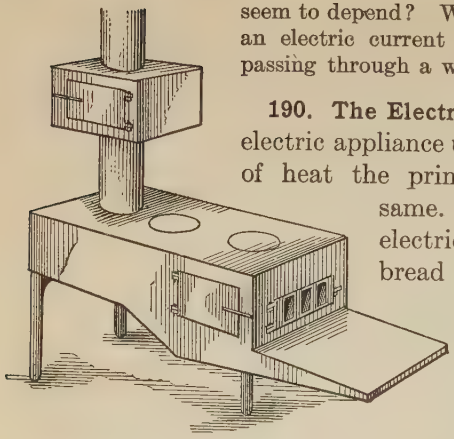


FIGURE 111B. — THE YANKEE STOVE.
How was this an improvement over the Stanley stove? Explain.

190. The Electric Heater. — In every electric appliance used for the giving off of heat the principle is exactly the same. If you examine an electric toaster used to give bread a delicate brown in toasting, you will find many coils of fine wire in its center. These coils offer *resistance*[1] to the electric current and become red hot, giving off much heat. The electric curling iron, heater, pad and other electric utensils are all made up of coils of fine wire. The same kind of coils are found under the seats in a trolley car, put there to

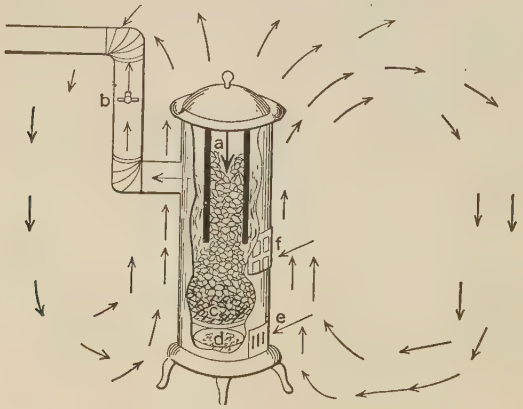


FIGURE 112A. — THE ROUND STOVE.
How is this stove like a Bunsen burner? Give the use of each part labeled.

[1] Resistance: the reducing of a current of electricity by a wire.

heat the car; they are also found in *rheostats* (rē′ō-stăts), which offer resistance in a line and prevent the overloading of the lights or carbons in a stereopticon or in a moving picture machine. Kitchen electric ranges for the cooking of all foods are now on the market. The time may come when

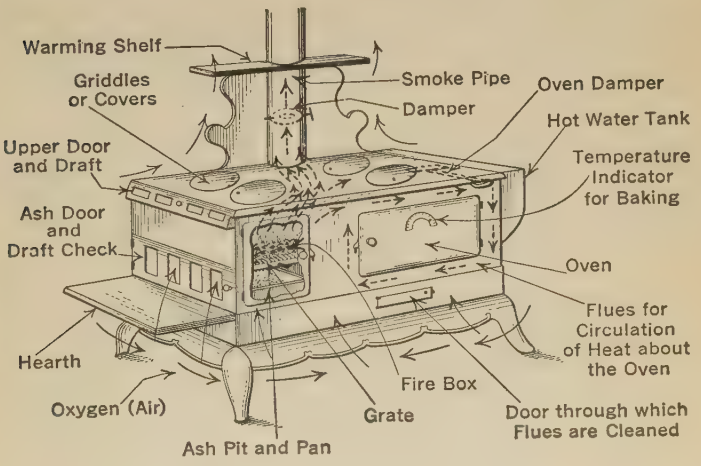


FIGURE 112B. — THE RANGE.

Compare this picture with 112a. Give the ways in which the two stoves are alike and different. Study each part and find out its use. Explain direction of arrows.

most homes will be heated and all food cooked by electricity generated by waterfalls miles away. We shall be heated by the sun. Explain.

191. The Work of Heat in the Cooking of Foods. — In the preparation of different foods, different temperatures must be used. The following simple table may be of some use to you in the home and may give you a basis for comparison.

A thermometer may be placed just inside the oven door. In improved stoves, either a metallic temperature indicator is set in the oven door or a heat regulator is attached to the

gas stove. In pasteurizing milk a thermometer without a wooden back is used.

	Degrees F.	Degrees C.
Oven temperature for baking:		
Sponge cake, cookies, bread, gingerbread, etc.	350–400	175–205
Pastry	450–550	230–290
Biscuits	400–450	205–230
Custards and puddings	250–350	120–175
Melting point for:		
Sugar sirup in making walnut brittle, etc.	315	155
Sugar sirup in making taffy and hard candies	300	150
Sugar sirup in making fudge	240	115
Pasteurizing milk	145	65

192. Factors Controlling the Cooking of Foods. — The boiling point of water is 212° F., provided it is boiled at sea level. But at Denver, Colorado, water boils at about 203° F. because Denver is at least 5000 feet above sea level and, as you know, the atmospheric pressure decreases as the altitude increases.

In places of high altitude pressure cookers are used to raise the boiling point of water so that foods can be easily and quickly cooked. The kind of kettle used and the presence of salt and other soluble materials also raise the boiling point of water. Explain.

5. How Heat Is Distributed in the Home

193. Heat and Temperature. — Our bodies are not true or reliable indicators of the *degree* of heat in a room. To detect the degree of heat we use a *thermometer* (Fig. 113) which measures the heat *intensity*. The unit of temperature is the *degree* (°). Heat that will affect the thermometer is called *sensible* heat. It is this heat which you *feel* when you enter a heated room.

On the other hand, when we speak of *heat*, we think of the amount of it in any given space or object. When we come to the comfort and enjoyment of our living rooms, we are most interested in their *temperature*. With a moist air 68° F. is quite warm; with less moisture 70° F. might be more satisfactory. A correct thermometer is the only safeguard, and every home should be well supplied with at least one for each floor.

194. History of the Thermometer. — Heat measurers were first constructed by Galileo in 1592. Before this date the determining of temperature was purely a matter of bodily sensation. If a surface or body of air was below the body heat, it was cool; if above the body heat, it was warm. In 1714 Fahrenheit developed the scale thermometer and placed upon it 32° as the freezing point of water and 212° as the boiling point of water. The difference is 180°. Zero (0° F.) is 32 points or degrees below freezing. All these points are merely arbitrary, as we can see when we observe the Centigrade scale, but they serve us as a basis for reckoning and comparison. Study the picture and learn how to compare the two scales and transpose one to the other. Practice on this until you can make the change quickly.

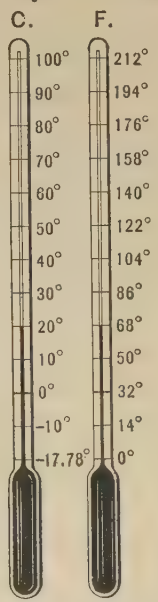


FIGURE 113. — TWO KINDS OF THERMOMETERS.

Note that 0° on the Centigrade thermometer (C.) is 32° on the Fahrenheit scale (F.). To change from the Fahrenheit to the Centigrade scale 32° must always be subtracted. Again, since 212° on the Fahrenheit scale is but 100° on the Centigrade scale, each degree of Fahrenheit's scale is but $\frac{5}{9}$ of a degree on the Centigrade scale. Thus to change 68° Fahrenheit to Centigrade first subtract 32°. This leaves 36 degrees. Then $\frac{5}{9}$ of 36 is 20° C. To change from Centigrade to Fahrenheit reverse the process. Try it.

(Key) Demonstration 25: ***Problem: How is heat distributed in your home?***

Materials: An empty vegetable can with several holes punched in its side near the bottom; a flatiron or any five-pound weight; a Bunsen burner; some wood splints; a beaker of water; an iron tripod; and sawdust (Fig. 114).

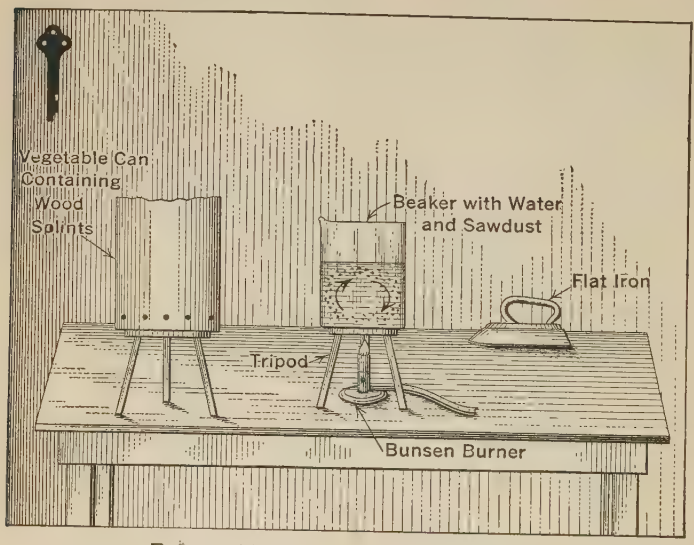


FIGURE 114. — (KEY) DEMONSTRATION 25.
Name two kinds and three forms of matter here.

Method: A. Build a fire with the sticks in the can, first placing it upon the tripod. Hold the hand upon the outside of the can as the fire burns.

B. Place the flat iron or weight on the tripod and heat it with the Bunsen flame. After five minutes remove the flame, hold the hand two inches from the iron or weight, and note what you feel.

C. Place the beaker of water on the tripod and place the flame just under one edge of it. Place upon the surface of the water a few particles of sawdust. Feel of the water from time to time. Watch the grains of sawdust carefully.

Observations: What do you feel through the side of the tin can? Whence does it come? Does tin conduct heat? Would the heat have come through, if the tin had been three or four times as thick?

Would the heat have come through iron the same way? Heat travels through metals by *conduction*. It passes from one molecule of the metal to another.

What do you feel on the hand when it is held near the iron or weight? Does the heat come through metal here? What is the medium for carrying the heat from the iron to your hand? Is the heat as intense here as in the case of the tin can? Is air a good conductor of heat? The heat comes to your hand across the space by *radiation*. Such heat may pass through space even where there is no air. What happened to the water, judging from your testing it from time to time? How did the heat get through the water? What happened to the sawdust grains? What did their path indicate? What effect does heat have on liquids in a receptacle? How does the warmed water get to the top of the beaker? How does the cool water get to the bottom? Which kind of water weighs the more? What has this difference in weight to do with the water movements? We say that heat is distributed here by *convection* (kŏn-vĕk'shŭn).[1] Heat may be distributed through gases in the same way.

Conclusions: By a study of the heating apparatus in your home determine what part of it throws off the most heat by conduction. Where in your home do you get heat by radiation? How is the living room in your home heated by convection currents? How is water sent about in your hot-water boiler? in your steam or hot-water heating plant? Give proofs for your statements. How is heat distributed in your home? Write this demonstration out in full in your Science Discovery Book.

195. Heat Conductivity of Materials. — But what of the ability of common household utensils to conduct heat? Is this of value or is it of no use to us? Wouldn't you like to prove this point once for all?

Suggested Experiment. — Confer with your teacher in collecting the materials for this experiment and then demonstrate the principle before the class. Your problem will be: Do all substances conduct heat equally well? Secure an iron ring stand; an iron ring; a Bunsen burner; a wire; a copper, an iron, and a brass rod each one foot long and of equal diameter; pea seeds or other objects of the same size; and paraffin. Attach the rods to the iron ring with the wire

[1] Convection: a transfer of heat by means of currents of gases or liquids.

so that they will all touch at one end. With the paraffin fasten three pea seeds to the other end of each rod at intervals of one inch. Place the Bunsen flame under the rods at their point of meeting. What happens and how soon does it happen? Account for this. From which rod do the pea seeds drop last? Account for this. What does this action indicate? Explain fully.

196. Heat Travels through Matter. — If one holds a metal poker for some time while tending a fire, he will find the handle becoming warmer and the time will come when it will have to be cooled or dropped. The heat actually travels the whole length of the poker by conduction. If now you put a wooden handle on the end of the poker, you do not feel this heat. Heat cannot travel well through the wood.

But how is this difference explained? In iron, the molecules are closer together than in wood and when heated strike one another with great force. In the wood, the spaces between the molecules are greater, the collisions of the molecules are less, and the heat cannot easily cross these spaces. Consequently, we say that wood is a poor conductor of heat.

In a gas, such as air, we find the best example of a poor conductor. Explain. The following table gives us a good idea of the relative heat conduction power of different substances.

Good Conductors	*Fair Conductors*	*Poor Conductors*
Iron	Limestone	Air
Brass	Brick	Wood
Copper	Glass	Sawdust
Zinc	Ice	Paper
Lead	Water	Cotton
Tin	Granite	Silk
Silver	Plaster	Wool
		Linen
		Asbestos paper

197. Practical Uses of Good and Poor Heat Conductors. — In cook stoves good conduction is needed and iron is the substance used. It is also cheap. On the other hand, light

metals like tin and copper could not be used in the same way. Explain. But in heating things over a fire good conductors are necessary, so we use copper and tin containers.

For the conduction of heat from the cellar to the rooms water is found to be a cheap and fair conductor. On the other hand, we find need of poor conductors to keep this heat in and so we use air in walls of houses, wool in clothes, paper

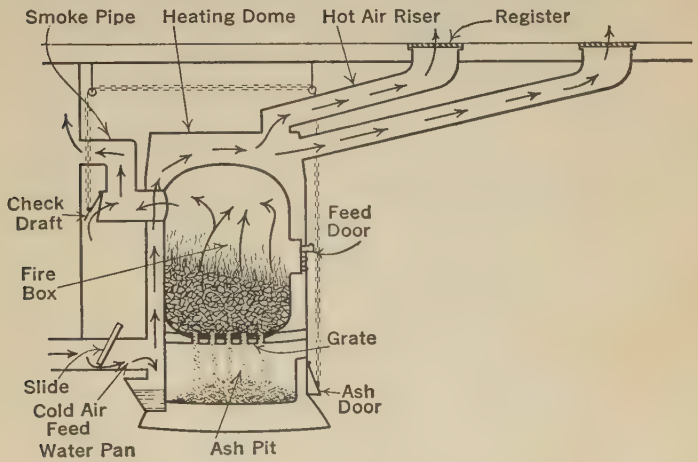


FIGURE 115A. — HOW A HOT-AIR FURNACE WORKS.

Study this picture carefully. Find out the use of each labeled part. Explain the connection between the ash door and the check draft. Explain the directions of the arrows.

sheathing on houses, and, for the same reason, asbestos covering on the furnace and steam pipes. Explain. How would heat be lost in each case?

198. Modern Heating Systems. — The invention of the hot-air furnace was a great advancement over the fireplace and stove in that masses of warmed fresh air could be sent through pipes into the rooms at different points. Steam and hot-water boilers provide heat to be sent through steam or water pipes to radiators, which warm the air coming in contact with them. This warm air circulates about the room

in convection currents, aided by open windows, by ventilators, or by a forced draft system.

199. The Hot-Air Furnace. — This type of heater is simply a large stove inclosed in a sheet-iron jacket or brick walls and set anywhere upon a cement floor. Study Figure 115a and answer the questions upon it.

In every hot-air furnace, a strong and constant circulation of air is the keynote to success. There should be no cross-currents but all cold air should join in a single stream in

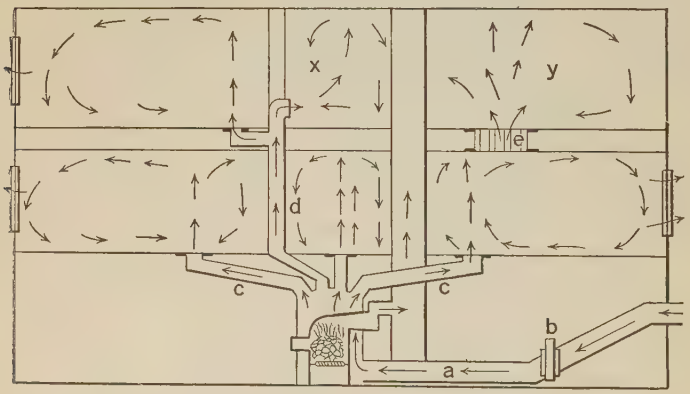


FIGURE 115B. — HOT-AIR HEATING SYSTEM.

a, cold air flue; b, cold air control; c, risers; x, warm air movements; e, register; d, hot air flue.

Find the chimney. What is the great advantage of this system? What is its disadvantage? Explain the movements of the arrows. What causes the cold air to enter?

flowing to the furnace. The warm air should always enter the rooms farthest from the windows. Little heat should be sent into the cellar. Explain each of these statements, giving a reason (Fig. 115b).

200. Air Movements in the Rooms. — When the warm air comes from a register into a room, it rises. Why? Where will it naturally go? Explain. What parts of the room will be coolest? Why? What will happen to the air

in these parts? Explain. What kind of air currents are set up? How, then, is the whole room really heated? Make a drawing of a room and show in it, by the use of arrows, the convection currents. Show by a plus sign the warm air and by a minus sign the cold air. Can you see any disadvantage of the hot-air furnace from the housewife's standpoint?. from the heating standpoint?

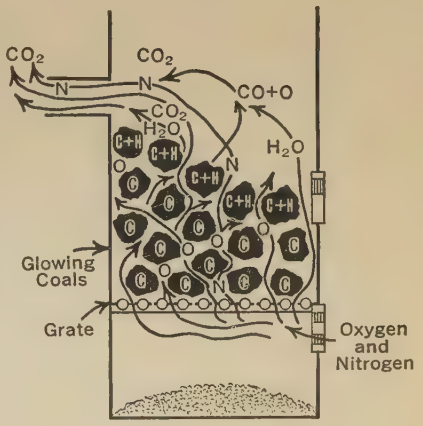


FIGURE 116. — WHAT HAPPENS IN YOUR FURNACE.

Account for every label in this picture, giving its use or origin.

201. Heat Distribution through Water. — Did you ever think about what happens to water when it gets hot? Does it do anything besides boil? Try the following simple experiment and find out the answer to this question.

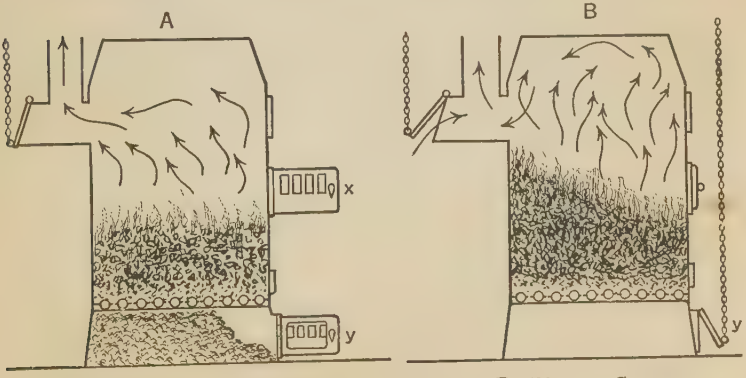


FIGURE 117A. — THE WRONG (A) AND RIGHT (B) WAY TO CONTROL YOUR FURNACE.

Why are **x** and **y** wrong in **A**? Show why the conditions are right in **B**.

Suggested Experiment. — Secure two Erlenmeyer flasks of the same size and weight, a platform balance, some cold water, and some hot water. See that the two flasks are exactly balanced upon the scales. Put the cold water in one flask and the hot water in the other flask. Fill both to the very top. What now happens? Which flask weighs the more? Can you explain this? What effect does heat have on matter? See Key Picture 8. If both hot

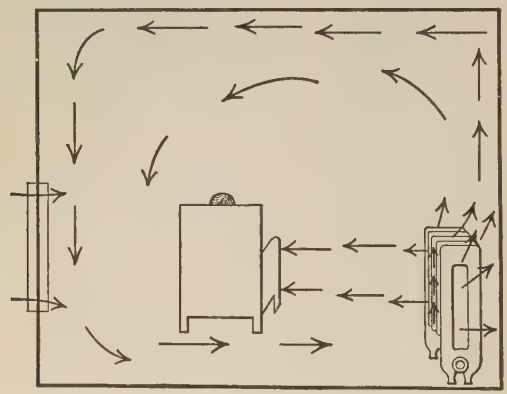


FIGURE 117B. — THREE KINDS OF HEAT DISTRIBUTION.

How does heat get out of the radiators? How does it get about the room? How does it reach the person in the chair? Explain fully.

and cold water were placed together in a tube, what position would each tend to take? What effect does heat have upon any given volume of water? What will happen to cold water in a heating plant when heated? What did happen to it in your demonstration with the hot-water heater?

202. The Hot-Water System. — In hot-water heating we depend upon the expansion and circulation of hot water through a closed system of pipes in the rooms, aided by the *radiation* of heat from the large surface of the radiator in each room. The heater is placed in the cellar and has a water jacket surrounding the fire box. The heat of the burning fuel passes through the boiler wall by *conduction*, the water is heated by *conduction* and *convection* and it circulates by *convection*. Explain this. With this preliminary explanation

trace out the system in Figure 118, answering all questions upon it. Then be able to describe the system in a connected story.

203. Some Essential Features of a Hot-Water System. — The circulation of the water in this system depends upon the unequal weight of two columns of water — one hot, the other cold. The heat is very even and comfortable. It takes longer to heat the rooms with this system than with any other, but on the other hand the rooms cool off more slowly. When may this be an advantage? a disadvantage? Explain the above statements.

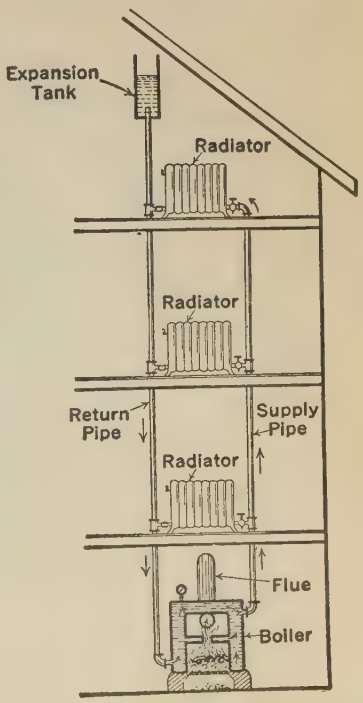


FIGURE 118. — A HOT-WATER HEATING SYSTEM.

Explain the use of each part shown. In houses of recent construction the expansion tank is closed and is placed in the cellar rather than in the attic.

204. The Steam Heating System. — This is by far the most common method of heating village and city homes to-day. The heat, pipes, and radiators are almost exactly like those of the hot-water system except that the radiators are supplied with air valves. Make a careful study of Figures 119a and 119b, considering the two drawings part by part. Be able to explain the working of the parts.

You know that if you put a quart of water in a dish over a fire, this water will begin to boil at a temperature of 212° F. or 100° C. The amount of heat required to cause this water to boil is *sensible* heat.

If this boiling keeps on long enough, the water will all be turned into vapor. No matter how long you boil this water it never rises above 212° F., but it requires 5.36 times as much heat to vaporize it as it does to bring it to the boiling point from the freezing point. Heat thus used to change

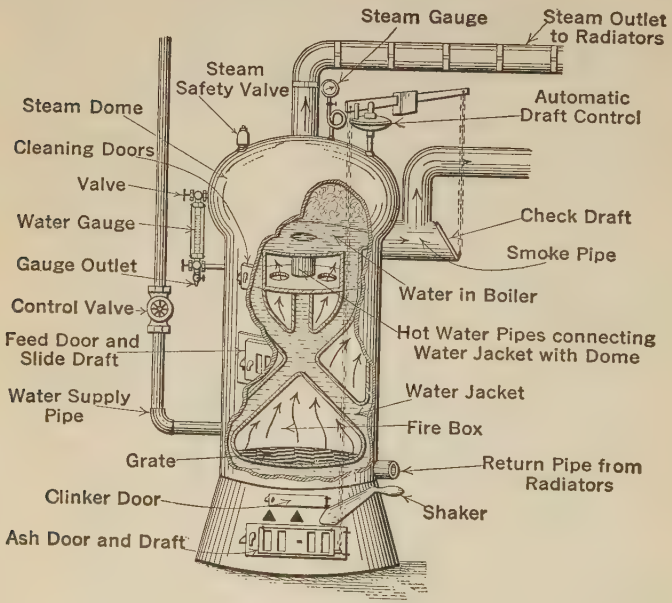


FIGURE 119A.—A STEAM HEAT BOILER.

Note the relations of all its parts. Show how they work.

the condition of matter (water from a liquid to a gas) without changing its temperature is called *latent* heat, because you cannot detect it with your senses. Nor will the thermometer show it. When heat is used to change a liquid into a vapor, it is called the *heat of vaporization*.

It is this insensible heat that rises with the steam vapor through the pipes and is used to heat the radiators in the rooms. As the steam gets farther away from the boiler it begins to condense and reaches its final stage of condensation

in the radiators. There it gives off into the iron exactly the same amount of heat as was used in vaporizing it. The water formed from the condensation of the steam returns to the boiler to be vaporized again. This is the principle of the steam heating plant.

205. Comparison of the Hot-Water and Steam Systems. — Carefully study sections 202, 203, and 204, and write out in your Science Discovery Book five marked differences beween the hot-water and steam heating systems.

Remember that the great defect of both systems is the lack of ventilation. In most cases windows have to be opened to secure fresh air. We know that moist warm air is more comfortable than dry warm air. Moreover, a house can be kept comfortably warm at a lower temperature with moist air than with dry air. In the hot-air furnace *humidifiers*[1] are placed in the furnace proper. In the steam system the escape of steam from the steam valves aids in humidifying the air.

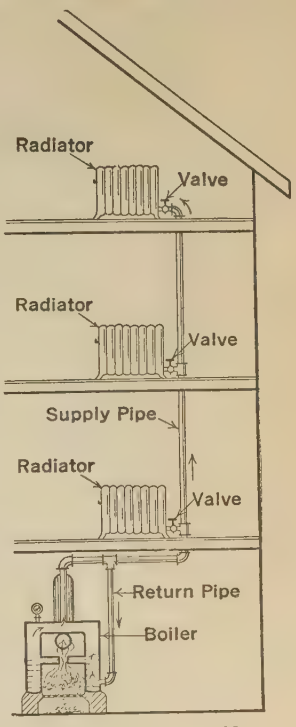


FIGURE 119B. — STEAM HEATING SYSTEM.

How does this differ from the hot-water system? Why is there no return line of pipe? What else is omitted? Explain fully.

206. The Conservation of Heat in the Home. — Many people conserve heat in the home by keeping all the windows and doors tightly closed. But this is a mistake and most unhealthful. Why? How can wall construction keep in the heat? (Fig. 120.)

[1] Humidifier: a water tank in the furnace, which moistens the hot air before it comes into the rooms.

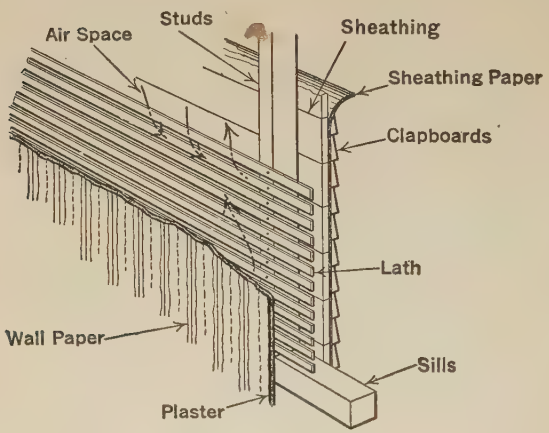


FIGURE 120. — HOW HOUSE WALLS ARE BUILT TO KEEP IN HEAT.

Give function of each labeled part. What parts help to keep heat in and cold out?

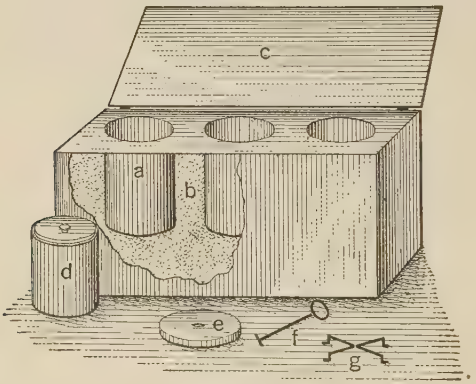


FIGURE 121A. — A FIRELESS COOKER.

a, cooking receptacle; **b**, insulating material (felt); **c**, cover; **d**, pot; **e**, iron heating plate; **f**, hook; **g**, metal frame.

The covers to pots and cooker are tight fitting. Why? Explain use of each part and the principle of the cooker.

If a shiny and a black piece of tin be placed at equal distances from a flame, it will be found that after a given time the black piece will be warmer than the shiny piece. In the heating plant, then, the pipes in the cellar should be shiny and left uncovered (especially in the hot-air system), while in the rooms the radiators should be painted a dark color. Explain. Steam pipes are often covered with asbestos in the cellar, but this radiates more heat, according to some experts, than the bare pipes painted with white shiny paint. The heater, itself, should be covered with a layer of asbestos cement.

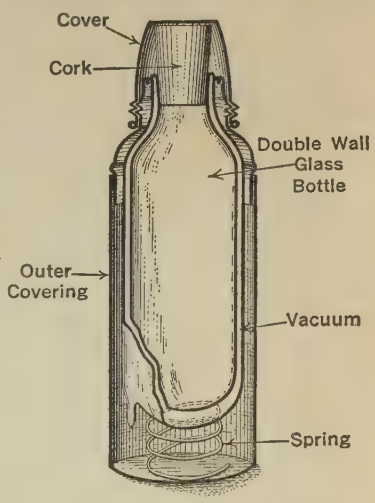


FIGURE 121B. — A THERMOS BOTTLE.

Explain the need for the vacuum, spring, double wall, and the cork. Explain the principle of this device.

The fireless cooker and the thermos bottle are other examples of schemes for the conservation of the heat produced by burning fuels and transferred to some solid or liquid. Study Figures 121a and 121b and be able to explain them.

6. DANGERS AND CONTROL OF FIRE IN THE HOME

207. The Control of Fire in the Home. — In the first place, it is necessary to see that all heating systems are so placed and so insulated that they cannot set any part of the house on fire. They should be fire-tight. Objects which can burn should not be left near them. Rubbish and papers should not be allowed to accumulate in the cellar. The flues should always be kept clean and the chimney in perfect order.

Popular Science Monthly.

FIGURE 122. — SOME COMMON CAUSES OF FIRE IN THE HOME.
All are due to carelessness. Why is electricity not included in the above causes?

Fires, many of which end disastrously, often break out in the chimney through the igniting of the soot. Study Figure 122 and determine some of the causes of fire in the home.

208. What to Do in an Emergency. — In school, help in the fire drills by thinking of what you are doing, refrain from talking, and keep in mind at all times just where the nearest exit is located. In your own home you should practice in

your mind what you would do if fire broke out while you were in any room of your home. If it did occur, you would no doubt do as you had thought you would do. It is also well to know just what to do with burns either on yourself or on others. Sweet oil will keep the air away until the doctor comes. A paste of baking soda and water will lessen the pain. Again, always remember that you should not start a fire with kerosene nor should you have any inflammable materials near you when handling a fire. If the clothing should get on fire, *never run*. Explain. Roll up in a rug or carpet, or wrap a blanket or quilt tightly about the body and this will smother the flames. Why?

FIGURE 123A. — A MODEL FIRE EXTINGUISHER.
Give the function of each part labeled.

209. The Fire Extinguisher. — Do you know how a fire extinguisher works? Would you like to make one?

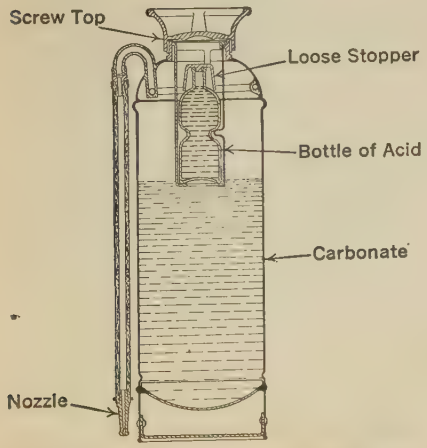


FIGURE 123B. — A MODERN FIRE EXTINGUISHER.
Give the function of each labeled part. Explain how this device works.

Suggested Experiment. — Just get together a wide-mouthed bottle, some bicarbonate of soda, some hydrochloric acid, a small pill bottle, a fine piece of wire, a piece of glass tubing drawn to a very small tube on one end, a one-holed rubber stopper to fit the large bottle tightly, and you are

ready to begin. Assemble the parts as shown in Figure 123a. Push the stopper in tightly and then tip the large bottle over. Note what happens in the bottle. Explain this. Now light a match and

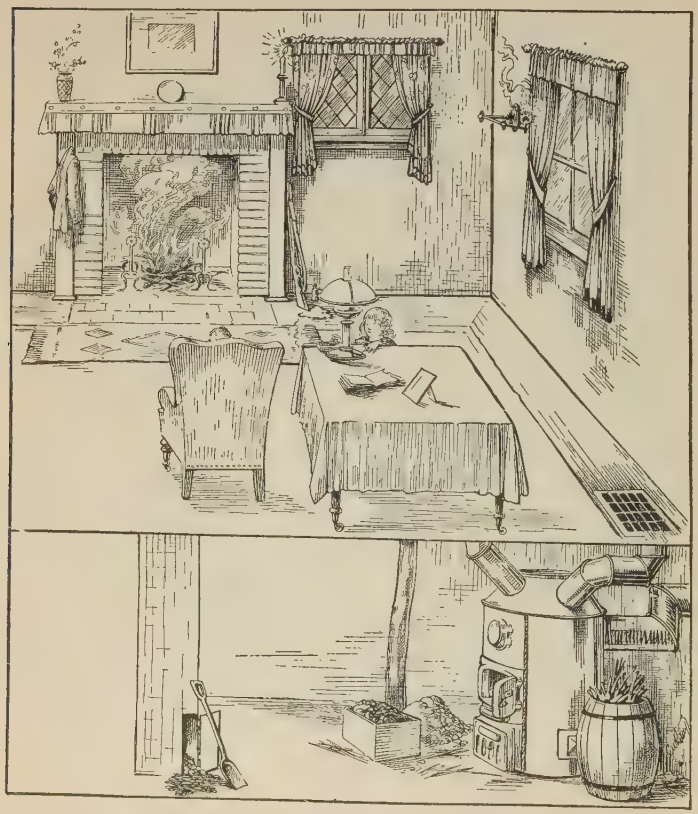


FIGURE 124. — FIRE HAZARDS IN THE HOME.

Point out here every condition which may easily cause a fire. Can you add others? Do you violate safety rules in your home?

as it burns direct the point of the glass tubing at the flame. What happens? Explain this. Now study a real fire extinguisher, read the directions upon its side, and tell why it is inverted for use and how it works.

FIGURE 125. — FIRE FIGHTERS AT WORK.

Above: A chemical warehouse fire due to spontaneous combustion.
Below: A spectacular test of fire fighting apparatus.

Good fire extinguishers should be placed at convenient places in the home (Fig. 123b). The carbon tetrachloride extinguisher is possibly the smallest and most easily handled form. The carbon dioxide type comes next. In buying any form be sure to learn just how to use it so that you will not become confused in an emergency. In case of fire, play the liquid or gas at the base of the flame. Do not inhale the gas.

There will be infrequent use of an extinguisher if you permit no dangerous fire conditions to exist in the home. Do you have any of the fire hazards shown in Figure 124 in your home?

Finally, remember the position of stairways and fire escapes. In case you have to flee a fire, if possible first tie wet cloths over the mouth and nose to absorb the smoke and crawl on the floor. Tie the bedding into a rope down which you can climb to safety, or if you must jump, throw out mattresses to break the fall.

REVIEW OUTLINE

1. The Importance of Heat to Man in: (1) Keeping him warm; (2) preparing his food; (3) causing growth in living things.
2. The Nature and Sources of Heat: A form of energy coming from: (1) the sun; (2) friction; (3) action of chemicals; (4) electricity; (5) oxidation of fuel.
3. The Production and Control of Fire: Produced by friction (wood, flint and steel, matches); controlled in: warming pan, fireplace, stove, furnace.
4. Effect of Heat on Matter. (1) Causes matter to burn; (2) expands matter; (3) changes solids into liquids and gases.
5. Fuels: (1) Nature; (2) origin.
6. Early Use of Fuels by: (1) Romans; (2) pioneers; (3) colonists; (4) people to-day.
7. Classes of Fuels: (1) Solid (coal, wood, peat); (2) liquid (petroleum); (3) gas (natural and coal gas).
8. Heat Values of Fuels: The calorie and the British thermal unit. Heat values of common fuels. Coal production: methods; amounts; wastes.
9. The Modern Stove: early types; later types; the electric stove.
10. The Use of Heat in Preparing Foods: Need of varying temperatures; methods of cooking different foods.

11. Heat and Temperature: Meaning of each; definitions. Temperature as a factor in heating a home; how detected and controlled by the thermometer. History of the thermometer; two types; comparison; Fahrenheit (Galileo).
12. Heat Distribution in Matter by: (1) conduction; (2) convection; (3) radiation. Good and poor heat conductors. Practical uses in the home.
13. Modern Heating Systems: (1) The hot-air furnace; (2) the hot-water system; (3) the steam system. Essential structure, advantages and disadvantages and principles involved in each type. Rules for the care of heating systems.
14. Conservation of Heat in the Home by: (1) pipe coverings; (2) wall spaces; (3) fireless cooker; (4) thermos bottle, etc.
15. Control of Fire in the Home: Dangers; prevention; (1) fire extinguishers; (2) removal of fire hazards; (3) drill on what to do in an emergency.

SUMMARY

It was by the burning of *fuels* that man found out how to produce a steady heat. When man discovered fire, he began to enjoy its warmth and to become civilized. Electric current is now furnishing a large amount of heat to man and may some day take the place of the burning of fuels.

Man but recently found out the effects of heat upon matter in expanding it and in changing its composition and nature. The greatest value of heat to him comes from burning fuels, thus warming him, cooking his food, running his factories and railroads. *Carbon* and *hydrogen* are the fuel elements which make fuels burn, and these elements may be in the form of a *solid* (coal), a *liquid* (petroleum), or a *gas* (coal gas). All early devices failed to get the maximum amount of heat out of fuels.

The modern heating plant aims to get the greatest amount of heat out of a given amount of fuel at a minimum cost and to distribute it to the places where it is needed. But this means a constantly greater demand for coal, which in time means a coal shortage. We must then turn to some other means of securing heat. This will probably be *electrical energy developed by water power*.

In buying fuel you should know the amount of heat it will produce. In heating a room, you are most interested in its *temperature*. To know what the temperature is requires a *thermometer*.

Heat is naturally distributed in three ways (by *conduction*, *convection*, and *radiation*). To use these natural methods to the best advantage, the modern heating devices have been invented (*hot-air*,

hot-water, and steam systems). Each system has its advantages and disadvantages. Once in use, great care and thought is needed in its care and control, if the best results are to follow.

Heat when produced should be *conserved* as much as possible because of the *increasing cost of fuel* and because of *added comfort.*

Finally, the fire hazards should be removed and the safety of the home increased by the installation of precautionary devices such as *fire extinguishers, asbestos coverings,* and *fire escapes* where needed.

Remember that :

1. Heat is a form of energy usually released by the oxidation of fuels.
2. Heat has become increasingly useful to man because of the great improvement in the devices for producing, controlling, and distributing it.
3. The amount of heat obtained depends largely upon the kind of fuel used and the way it is burned.
4. The action of heat upon matter and its natural method of distribution are most important factors in its use.
5. The increasing uses of heat in the home make the need of a careful handling of fires and heating apparatus most important.

THOUGHT QUESTIONS

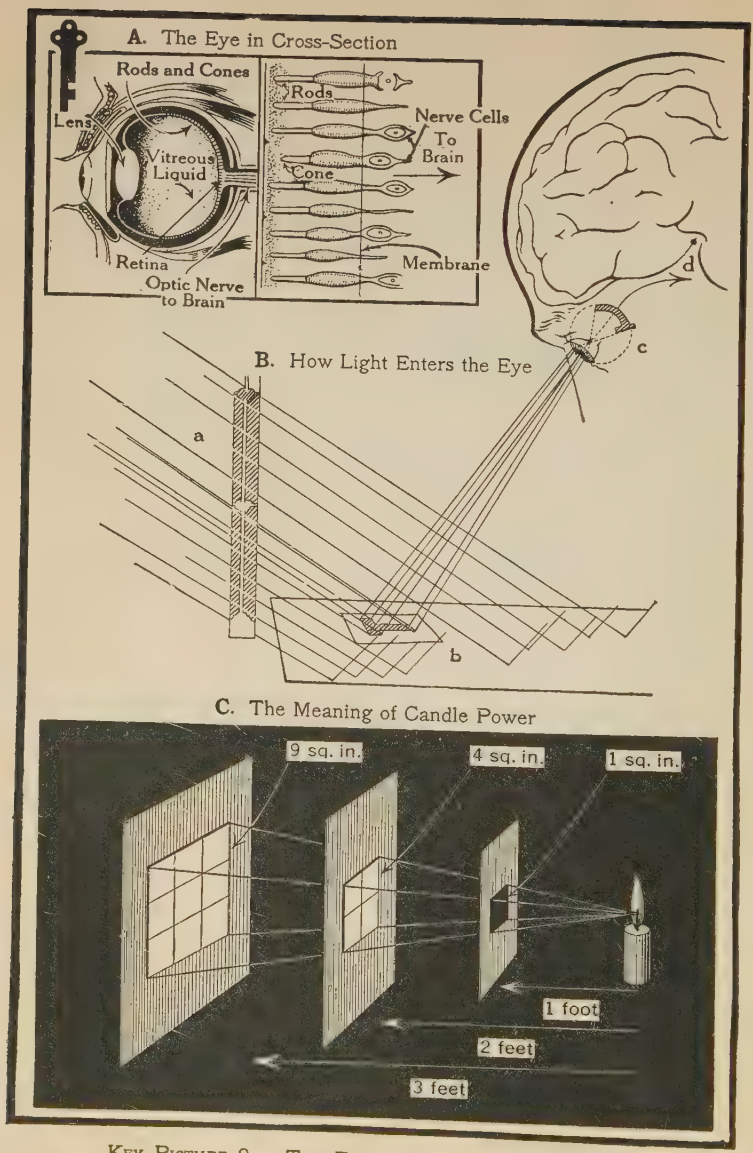
These questions are put in this book for a real purpose. They were thought out for your special use and they aim to give your mind some real exercise. They cannot be answered by anyone who does not know his science. They are meant for the real student who has carefully developed a sure foundation in the preceding chapters of this book. These chapters are like the foundations of a house. You cannot build the walls without this foundation. So these Thought Questions are the walls, the decorations, and even the furnishings of your mental house. They make it beautiful. They help make a complete scientist just as the decorations and furniture make a complete home. Use these Thought Questions to develop your power to think. Then, think out some new ones to try on your classmates.

THOUGHT QUESTIONS

1. What is the advantage of a fireplace? Why are fireplaces still used?
2. What is the advantage of a stove over a fireplace?
3. What causes a draft? Explain. Study Key Picture 8.
4. Why does a fire smoke when first started in a stove or furnace?
5. Which kind of material would you choose for building a house in the tropics — wood, stone, or steel? in cold climates? Explain.
6. Why are flatirons often fitted with wooden handles?
7. Why are thermos bottles shiny?
8. Give two reasons why the bottle in a thermos is placed upon a spring.
9. Why do rubbers make the feet feel too warm, if worn in the house?
10. Why do thick glass tumblers break when hot water is suddenly poured over them?
11. Why do thin glasses seldom break when heated suddenly?
12. Why does a thermometer " drop " when first placed in hot water?
13. Why does a clock with a metal pendulum have to be regulated every summer and every winter?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Allen. Sweden and Safety Matches. Ginn and Co.
Burns. Story of Great Inventions. Harper and Bros.
Butler. Household Physics. Whitcomb.
Gibson. The Romance of Coal. J. B. Lippincott Co.
Green. Coal and the Coal Mines. Houghton Mifflin Co.
Hill. Fighting a Fire. Century Co.
Spingett. Cold Storage and Icemaking. Isaac Pitman and Sons.
Weeks. Avoidance of Fire. D. C. Heath Co.
Whitman. How to Make a Thermometer. General Science Quarterly, May, 1920.
Wilson. Coal. Isaac Pitman and Sons.



KEY PICTURE 9.—THE EYE, LIGHT, AND ILLUMINATION.
Try to understand these pictures before you read the chapter.

CHAPTER IX

OUR USE AND CONTROL OF LIGHT

See how that beam of seeming white
Is braided out of seven-hued light
Yet in those lucid globes no ray
By any chance shall break astray.
— Oliver Wendell Holmes.

All wish to know, but few the price will pay. — Juvenal.

What Do You Know about Light?

Did you ever stop to think what light is? Suppose that the sun should be blotted out. What do you think would happen then? Try to think of the many ways in which light is useful to you. How do you know that light exists? Would you like to know how you see? Would you like to know the best way to light your home? Do you think it of advantage to know which kind of light is the best and cheapest? Here are some questions which will occupy your thought for some time.

Some Practical Questions:

1. Why are light colored walls in houses more cheerful than dark colored walls?
2. Why does an object cast a shadow?
3. How can light be thrown from one object to another?
4. Why does an image appear upside down in the back of a camera?
5. What causes the yellow flame of the lighted candle?

Home Problem. — Secure a magazine of interior decoration. Make a special study of the location, strength, and type of lights used for the living rooms. Now compare with the lighting arrangement in your own living room and suggest changes and improvements.

Field Problem. — Make a survey of the street lighting plan of your home town or city, determining the kinds, strength, and position of the lights. Determine if the lights are properly placed to give the most light. Suggest improvements. Find out the source of these lights. Visit the power house or gas house and learn all you can about them. Report to the class.

1. How Sunlight Travels

210. The Importance of Light. — The sun sends off its rays of light to us through a distance of over 92 million miles. These rays allow us to see objects, they keep the earth from becoming a frozen, lifeless mass, and they cause our crops to grow. Some might think that without sunlight we could use artificial light, but this would be impossible, for artificial light is produced by burning fuels or by water power, and without the sun these would not now exist. Can you explain this?

211. What Is Light? — Scientists tell us that light is caused by the vibration of waves of ether (something which fills all space between molecules of matter). These waves, vibrating at the rate of billions of times per second, travel from the sun to the earth. We do not yet know much about the real nature of light, but you as a young scientist can easily find out some things that it does.

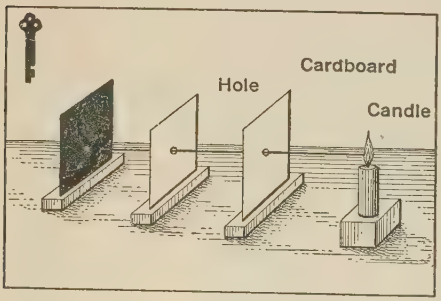


Figure 126. — (Key) Demonstration 26.

Do the rays of light shine out from the candle in all directions? What are the only rays that can pass through the holes? What must be the relation of the holes to each other?

(Key) Demonstration 26: ***Problem: Can light rays shine around an object?***

Materials: Blocks of wood fitted with cardboards with a $\frac{1}{8}$" hole punched through the center of each and a candle fastened to a wooden block. Arrange the parts as shown in Figure 126.

Method: Light the candle and place one of the cardboards so that you can see the candle light through the hole. Next, place the second cardboard so that you can see the candle light through the holes in both boards when they are placed about one foot apart. Now move one of the cardboards a fraction of an inch to the right. Do you see the candle light?

Observations: Does the light travel in crooked lines? How does it travel? Would it be possible for a candle to throw its light around the edge of one of the cardboards so as to illuminate an object behind it? Explain. Record your observations in your Science Discovery Book.

Conclusion: Write out your conclusion after studying your problem. Give your proofs.

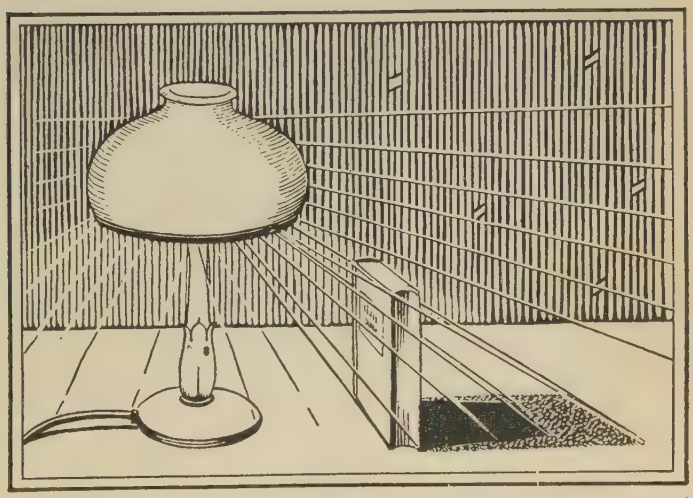


FIGURE 127. — CAUSES AND PARTS OF SHADOWS.

Can you name the parts of this shadow? What causes these parts to appear? Try this out at home tonight.

212. Shadows. — The fact that light rays travel in straight lines accounts for the shadows behind every *opaque* object which is exposed to them. Those rays which strike the opaque substance, not being able to pass through it, are either absorbed or reflected. This casting of shadows causes our night and eclipses of the moon and sun. Can

you explain this? The different parts of a shadow vary in intensity. Test this out for yourself as shown in Figure 127. The center is called the *umbra* and the lighter portion about this center is called the *penumbra*. In your home, it should be your endeavor to get as much direct light as possible without a glare and to prevent shadows with large umbras. You should, therefore, keep out of the windows such objects as potted plants and chairs, which cut off light and form large shadows. Plants have no place in the windows of living rooms unless the rooms are abundantly supplied with light. Aquaria may be placed in windows without cutting off much light. Explain.

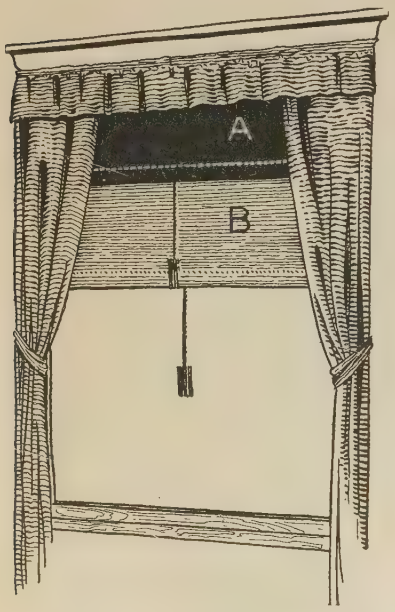


FIGURE 128. — THE USE OF CURTAINS.

Give the use of each kind of shade here shown. Why does the light pass through one and not the other?

213. Sources of Light. — When the sun is obscured by clouds, we have a dark day. When the sky is clear, the light rays shine directly upon all objects, causing them to be illuminated and making them plain to the eye. The prime purpose of *transparent* window glass is to let in these light rays. To cut off some of this light, we use *translucent* curtains of a pleasing shade. To shut out all light we use green or black opaque curtains (Fig. 128).

214. How Light Travels. — Light is a form of energy. It travels in straight lines in every direction from its source,

at the rate of 186,337 miles a second. It thus takes about 8 minutes for a light wave to travel from the sun to us through a distance of over 92,000,000 miles. The waves of the invisible ether give us light when their rate of vibration is between 750 trillion and 400 trillion times a second. At this rate, the waves of ether affect the optic nerve of the eye and we see. The source of these ether waves is the sun. (Key Picture 9.)

FIGURE 129. — REFLECTED LIGHT OUT OF DOORS.

What causes the clear images in the water? How does reflection add to the beauty of the home and of the landscape?

2. How We Use and Control Sunlight

215. Why Things Are Visible to You. — When a candle gives light, the rays pass off from the source of light in straight lines in every direction. But if you look at the wall opposite the candle, you find it lighted by the candle and the rays strike back from the wall to your eyes by *reflection*[1] (rē-flĕk'-

[1] Reflection: a turning or throwing back of light rays from a surface.

shŭn). Practically everything you see indoors and out of doors is visible to you by reflected light (Fig. 129). Tree trunks absorb light. A white house reflects light. Name several good and poor reflectors of light which make them easily or poorly visible to us. (Key Picture 9.)

216. Reflected Light in the Home. — People who can get the direct rays of the sun in most of their rooms all day are very fortunate. Others must depend upon reflected light. Draperies, heavy curtains, and dark upholstered furniture are to be avoided in homes with poor lighting. Explain. Polished surfaces, bright ceilings, glassware all tend to lighten up rooms. What is the advantage of light colored ceilings? Explain.

Make a careful study of your home to find all reflecting surfaces which help to light the rooms. Observe if any different arrangement of the furnishings will give you more light.

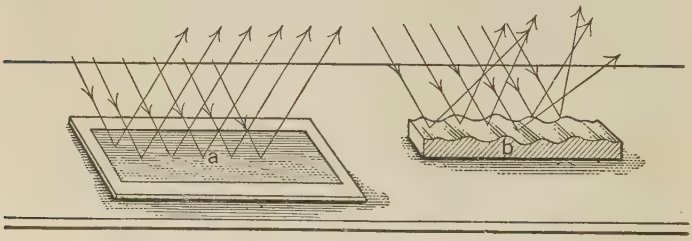


FIGURE 130. — TWO KINDS OF REFLECTIVE SURFACES.

a, smooth and plane; **b**, rough and uneven. Account for the direction of the arrows in each picture. Which surface is hard on the eyes? Explain. Which gives the softer light? Explain.

217. Diffused Light in the Home. — If you depended entirely upon reflected light in the home, your eyes would soon be ruined. A shining ceiling would soon become tiresome. A slightly roughened, tinted ceiling furnishes you with much light without tiring you because the light is scattered or *diffused* from every little irregularity in the surface. This gives a soft and pleasing light. Study Figure 130 and explain it.

218. Refracted Light in the Home. — Light rays to be *refracted* (bent to a new course) must pass from one transparent medium into another. Water is the most common refractive substance. This accounts for the distortion so commonly seen in water in the aquarium, in jars or bowls of water, and in the window glass if the edges are somewhat distorted or the surface irregular. Diamonds and similar brilliants owe their sparkling lights to the refraction caused by their *prismatic*[1] surfaces. Do diamonds reflect light?

219. Color in the Home. — The color of an object depends upon what light rays it transmits, absorbs, or reflects. An object appears black when it absorbs most of the light rays of all colors and reflects few to the eye. It is white when it reflects most of the light rays of all colors and absorbs few. Make a list of the distinct colors you can see in your living room at home. Do these colors in any way brighten or darken the room? Decide upon several fundamental colors which would be proper for a living room, dining room, or bed room. Study your own rooms at home and work out suggestions for improving the color scheme the next time you paper and decorate.

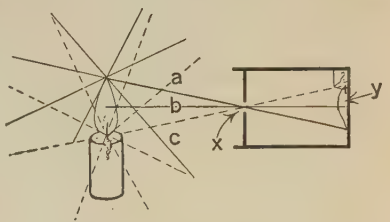


FIGURE 131A. — THE PINHOLE CAMERA.

a, **b**, and **c** are light rays from different parts of the candle. They must pass through the hole **x** and strike the back at **y**. Why do not the other rays pass through the hole? Why is the image inverted?

220. How Does a Pinhole Camera Use Light Rays? — Here is an experiment you can surely do at home. You will certainly be surprised at the results. Moreover, they will make clear a great many things. Study Figure 131a, and be able to explain it.

[1] Prismatic: a term applied to objects having many plane surfaces.

Suggested Experiment. — Find an empty cereal box, a candle, and some tinfoil. Cut a square hole one inch in diameter in the bottom of the box. Paste the tinfoil over this hole. Carefully prick a hole in the center of the tinfoil with a pin. Cover the open end of the box with a piece of thin tissue paper. Place a lighted candle before the pinhole. Darken the room or put a dark, opaque cloth over your head and the paper end of the box. What do you see on the paper? Is there anything peculiar about this image? Bring the box forward or backward and note the effect upon the image. This box is a crude camera. Make a side sketch of this camera and candle and try to account for the position of the image on the paper by drawing lines from several parts of the candle to the corresponding parts of the image. What effect does a small opening have upon light rays? Give your proofs. Is the image made by direct, reflected, refracted, or diffused light? Explain. Give a complete story of the above in your Science Discovery Book.

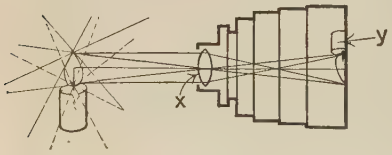


FIGURE 131B. — A BELLOWS CAMERA.

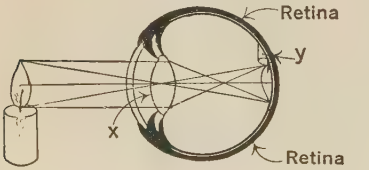


FIGURE 131C. — INTERIOR VIEW OF HUMAN EYE.

Compare b with a. What new structure is added in b? Now compare c with b. What new structure is found in c not found in b or a?

3. How Your Eyes Use Light

221. How Do You See with Your Eyes? — This question should be an interesting one to you. You can solve it in school only, for the materials to be used are expensive.

Suggested Experiment. — Secure from your teacher a model of the human eye and borrow a bellows camera (Figs. 131b and 131c.) Compare the model of the eye with the camera and discover all the parts of each which are similar. Locate the lens and iris-diaphragm in each. Find the ground glass in the camera. Look for the retina in the eye which corresponds to the ground glass.

Look through the back of the camera and focus it upon some object. Note the way you focus it and explain it. Now look through the back of the eye and focus it also. Does it focus in the

same way? How do objects look in both the camera and the eye? Account for this. Where do the light rays meet? Where do they cross? How are images focused in the eye? Make a study of the eye to understand all its essential structures and their uses. Give an account in your Science Discovery Book of how you think the eye sees. (See Key Picture 9.)

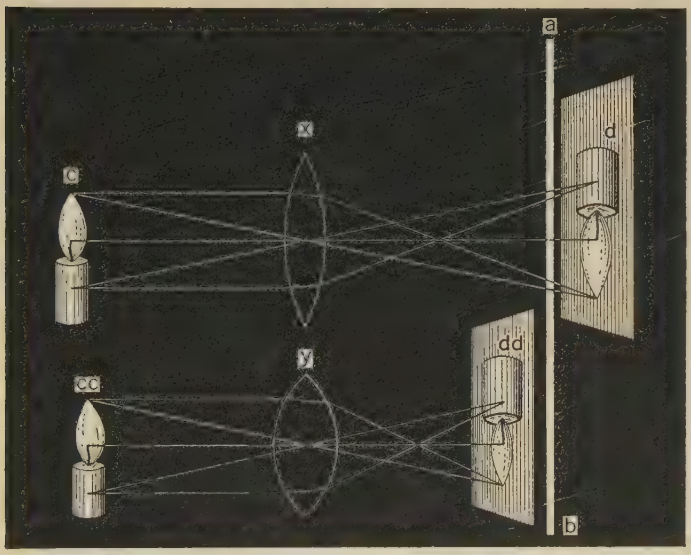


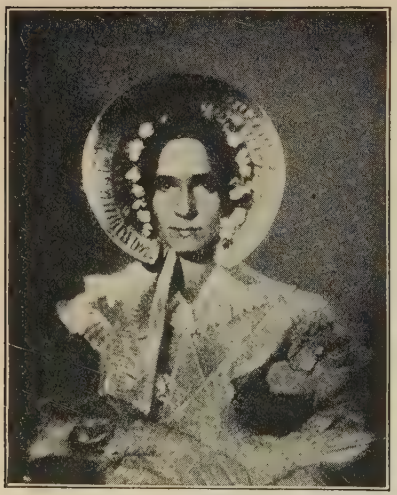
FIGURE 132. — WHAT LENSES DO TO LIGHT RAYS.

x, a thin convex lens; **ab**, any surface; **y**, a thick convex lens. Light rays from **c** are bent by the lens **x** and produce an inverted image back of the surface **ab**, at **d**. Light rays from **cc** pass through **y** and produce a clear image in front of the surface **ab** at **dd**. Can you explain the difference? Why is the image not thrown on **ab**?

222. The Importance of the Lens. — A prism refracts rays of light while a lens not only refracts but may also converge[1] light rays.

When a lens is cut so that its center is thicker than its edges, it is said to be *convex* and it focuses the rays of light passing through it at a point near it. It is this kind of

[1] Converge: bring together.



Popular Science Monthly.

FIGURE 133A. — THE FIRST REAL PORTRAIT EVER TAKEN WITH THE HELP OF SUNLIGHT.

lens which is found in the eye, camera, and the object glasses of the telescope, opera glass, and reading glass. (Key Picture 9.)

Sometimes lenses are made so that the center is thinner than the edges. These are called *concave* lenses and are used to cause the light rays to diverge. By combining these two kinds of lenses in different ways we may have a series so adjusted that the light rays may be diverged and converged. The result is to magnify an object and then focus it so that it can be plainly seen as a large object, though really invisible to the naked eye. (Fig. 132.)

223. The Camera. — The convex lens is used in the camera to great advantage because a landscape possibly miles across can be focused in all its details on a sensitive plate 4 by 5 inches in dimensions. The image is always inverted on the ground glass. Why? Study a camera (Fig. 133b) carefully and understand the reason for the position of the bellows, the purpose of the iris-diaphragm, the bellows, the black interior of the bellows, the use and structure of the finder, and the use and importance of the stops.

Popular Science Monthly.

FIGURE 133B. — THE FIRST FOLDING KODAK EVER MADE (1892).

It was heavy and cumbersome.

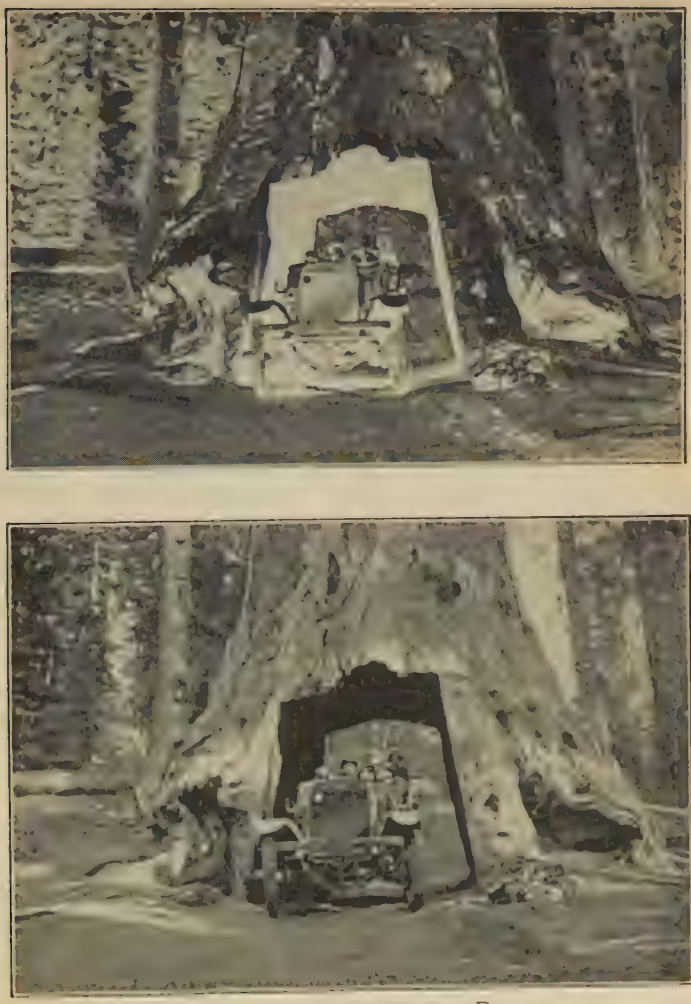


FIGURE 134. — A NEGATIVE AND A POSITIVE.

Compare the two pictures. In the *negative* (above) the light objects of the scene are dark and the dark objects of the scene are light. This is caused by the action of the sunlight on the silver salts in the plate. In printing the *positive* (below), the lights and darks are again reversed, giving a reproduction of the scene.

The modern photograph (a writing of light rays) is the result of the discovery that light can be made to do work chemically upon certain salts containing silver. When exposed to light for the fraction of a second, as in a "snapshot," these silver salts are affected more by intense light rays and are little affected by the less intense rays. These differences are brought out by developing the plates.

The print or finished picture is made by exposing sensitized paper to light passing through the negative. The light part of the negative allows the light rays to pass through easily while the dark parts hold them back. When the print is developed, its lights and darks reverse those of the negative, reproducing those of the original object. Study the illustrations in the text (Fig. 134) and be able to explain them.

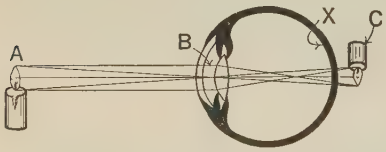


FIGURE 135A. — FARSIGHTEDNESS.

The lens **B** is too flat or the eyeball too short from front to back. The candle image tends to become focused behind the retina **X** at **C**. Explain.

224. The Human Eye. — Were it not for your eyes you could not enjoy pictures or anything about you that delights the eyes. The eyes are the most delicate organs of the body, the most easily and commonly abused, and the ones that require the most care and consideration.

Your study of the principles of the camera prepares you to understand the structure of the human eye. When a ray of reflected light reaches the *cornea*, it passes through the *aqueous humor*, through the *lens*, and through the *vitreous humor*, and is refracted and brought to a focus on the *retina* in an inverted position. There the nerve endings are stimulated, thousands of impressions are carried to the brain, where they are put together as a whole to form the object seen, and we say we see a dog or an automobile or a house. Study the diagram of the eye (Key Picture 9) and learn all the parts and their uses.

225. Control of Light in the Eye. — The pupils of the eyes of a cat are largest on a dark day or at dusk. By examining your own eyes in a looking-glass you will find the same thing to be true there also.

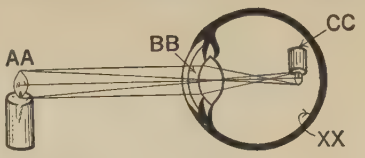


FIGURE 135B. — NEARSIGHTEDNESS. By comparison with Figure 135a explain this defect.

In the camera the amount of light allowed to enter is determined by the stop or diaphragm aperture. When should it be opened wide? When should it be stopped down to a small opening? To bring an object into focus the lens is moved forward or backward. How are these same things accomplished in the human eye? Have one of your companions shut his eyes for a minute and then open them towards strong light. Try it again, opening them towards dull light. Compare the results and account for them. What are the advantages of these movements? What would happen if it were not possible to perform them?

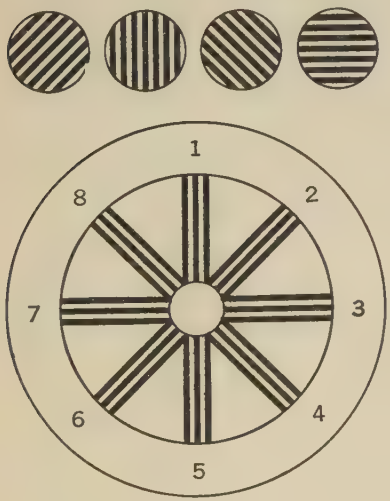


FIGURE 135C. — EYE CHART. An uneven surface of the cornea or of the lens produces a condition known as astigmatism. Do all the black lines seem of the same degree of blackness? If not, you have some astigmatism.

The *ciliary* (sĭl′ĭ-ā-rĭ) muscles of the eye have the power to flatten or thicken the crystalline lens so that an object is properly focused on the retina. This is called *accommodation*. This is a wonderful adaptation and you are totally unconscious

of it. If an object is far away, in what form will the lens be found? Suppose one is reading steadily for some time and then looks off suddenly, what will happen to the lenses of his eyes? Explain. Can you tell why the eyes sometimes pain one when this is done? The eyes have a great advantage over the camera in that they can move from side to side to take in a wider vision. This they are able to do because they are set in a bony socket of the skull and protected by fatty tissues. In this soft setting they are easily moved by the muscles. The eyelids act as the shutters of the eyes, closing out all light or letting in much light at the wish of the owner. The hairs on the lids keep out dust and perspiration. Study Key Picture 9.

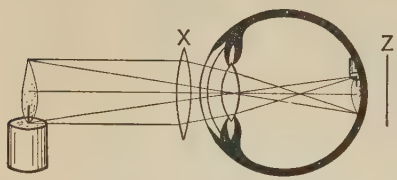


FIGURE 135D. — CORRECTION FOR FARSIGHTEDNESS.

Here the convex lens **X** brings the image from **Z** to the retina. Figure 135a is corrected. Explain.

226. Eye Defects. — Most infants when born have normal eyes and eyesight. But as time passes the eyes become misshaped or strained so that at school age a surprisingly large number of defective eyes are found among children. Too many young and middle-aged people have to wear glasses and no doubt many more who do not wear them should do so. Study carefully the diagrams (Fig. 135, a to e) showing eye defects and their correction until you understand them.

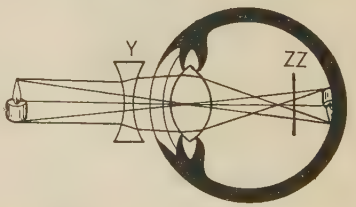


FIGURE 135E. — CORRECTION FOR NEARSIGHTEDNESS.

Compare with Figure 135b and tell what the concave lens **Y** does.

227. Care of the Eyes. — The eyes demand the greatest care. Right habits concerning them should be formed early in life. A few rules based upon your previous knowledge

of light and cleanliness are here suggested. As you read each one of them try to give the reason for such a rule and show how the neglect of such rules may lead to permanent injury to the eyes.

1. Do not make a steady practice of attending the moving picture theaters.
2. Whenever you attend a motion picture theater never sit in the forward part of the auditorium, if you can possibly avoid it.
3. Do not read while lying down.
4. Do not read a book with highly glazed paper in a strong light.
5. Do not make a practice of reading upon moving trains.
6. Do not read with the light coming from in front of you.
7. Do not read in a flickering light.
8. Do not rub the eyes with the fingers. Use a clean handkerchief. If the eyes are irritated, bathe them in a saturated solution of boracic acid.
9. Rest the eyes from time to time when engaged in fine work by looking off at a distance for a few moments.
10. Do not read books with extremely fine print.
11. Do not attempt to read in the twilight.
12. Do not look at extremely strong light for more than a moment.
13. Do not rub the eyes to remove any foreign substance. Float the substance out with an eye wash or turn the lid over a match stick, locate the substance, and remove it with a silk handkerchief.
14. Bathe the eyes from time to time in cold water.

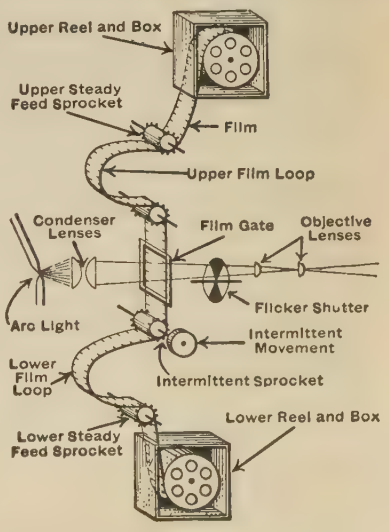


FIGURE 136. — THE ESSENTIAL PARTS OF A MOVING PICTURE MACHINE.

Study each labeled part and determine how it works.

228. Moving Pictures. — A moving picture film is a thin strip of transparent celluloid one inch wide and of indefinite

length. Upon this film are printed and developed 16 pictures to every foot, each picture differing from the one before or after it by the slightest detail. This film is run through the moving picture machine at a speed of more than one foot a second. An image remains on the retina about $\frac{1}{10}$ of a second. When pictures are moved before the eyes at the rate of sixteen times a second, each succeeding picture is placed in front of the eye before the image of the previous picture has died out. For this reason the moving picture is possible. The audience gets the impression of movement, although there is no movement whatever in the picture as it is seen. The movement really occurs when the flicker shutter revolves

FIGURE 137. — MOVING PICTURE FILMS.

Examine these films. Do they move? Note the bodies of the people in the several pictures. Explain the principle of the moving picture.

so as to shut off the light rays while one picture is being moved and the other brought into position. Study Figure 137.

4. How Artificial Light Is Produced and Controlled

229. Artificial Light. — Much of the world's work is done by night; our studying and most of our entertainments and educational gatherings occur between 8 and 10 P.M. Therefore, a study of the ways artificial light is produced and controlled should be of great interest to everyone.

230. How Does a Candle Give Light? — Suppose you answer this question by an actual test.

Suggested Experiment. — Secure a paraffin candle, pliers, and a $4'' \times 5''$ glass plate. Light the candle. Note any change which takes place in the paraffin. With the pliers clasp the wick halfway down to the candle and stroke upwards. Examine the pliers

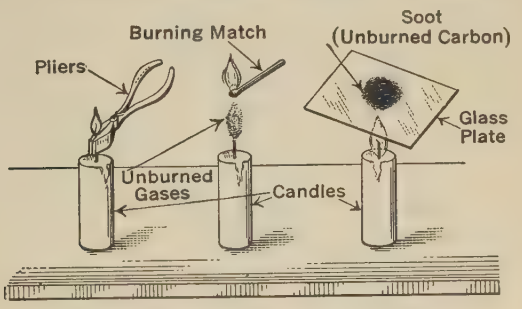


Figure 138. — The Candle Flame.
Explain the use of each part here shown.

and note what you see. Blow out the candle and immediately hold a lighted match within one-half inch of the tip of the wick. Note what happens. Hold the glass near the flame for a moment. Note the result. Fan the flame and compare what you see coming from it with what you have on the glass. Now lower the glass so that the flame tip touches it. Note results. Lower the glass still farther until it is halfway down the flame. Compare the results now with those first noted (Fig. 138).

What happens to the paraffin when the wick is lighted? What is found in the end of the wick after the candle burns some moments?

What catches fire when the match is held near the wick? What really burns in a candle? Is this substance which burns a gas, a liquid, or a solid? What substance is found in a candle flame? Give proof. What really happens when a candle smokes? What is smoke? Why do you not see this smoke when the candle burns steadily? When does the candle give the most light? What in the candle gives the bright flame? Where in the flame is the most carbon found? What is burning in the blue center of the flame? Where do you think the hottest part of the flame will be found? Give your proof. Test this by holding a wood splint horizontally in the middle of the flame. Observe the result and tell what it shows.

Conclusion: How does a candle give light? Give proofs and explanations.

231. Candle Power in the Home. — The candle as a means of effective illumination is a thing of the past. Still, all our methods of measurement of artificial lighting to-day are based upon the candle, for the unit of illumination is the *foot-candle* or the brightness of light received by a plane surface from a candle light one foot from it. Study Key Picture 9 until you understand it. The problem of successfully lighting any room in your home is not a matter of using candles but *candle power*, keeping in mind the use you want to make of the light and the distance between the light and the work to be done. The following table will give one a general idea of the illumination required for any work.

Library, living room.....2 to 3 foot-candles.
General illumination of house.....1 to 2 foot-candles.
Desk illumination or study .....3 to 5 foot-candles.

Thus if you decide that you will need 4 foot-candles in your study and the light must hang 4 feet above the desk, you will need a 64 candle-power light in order to give you the correct illumination.

232. How Does a Kerosene Lamp Work? — In small villages and in the country the kerosene lamp is still in use. How does it work? You can find this out for yourself.

Suggested Experiment. — Secure a small kerosene lamp, a piece of tin 4″ × 5″, and a lamp chimney. In the presence of your teacher, light the wick of the lamp. Note the condition of the flame. Hold the tin over the flame. Note the results. Now place the chimney on the lamp. Note the effect upon the flame. Wind a cloth around the burner. Note results. Examine the burner and determine its construction and the uses of its parts. In what condition is the fuel found? In what condition does it burn? What burns in the fuel? Turn up the wick. Why does the flame smoke? What will stop the flame's smoking? What causes the flame to give a better light? What kind of air currents are used here to give a draft? What is the use of the draft in the lamp? What actually gives light in the lamp? What produces the bluish part of the flame? How does a lamp control a flame? Give full proofs in your Science Discovery Book.

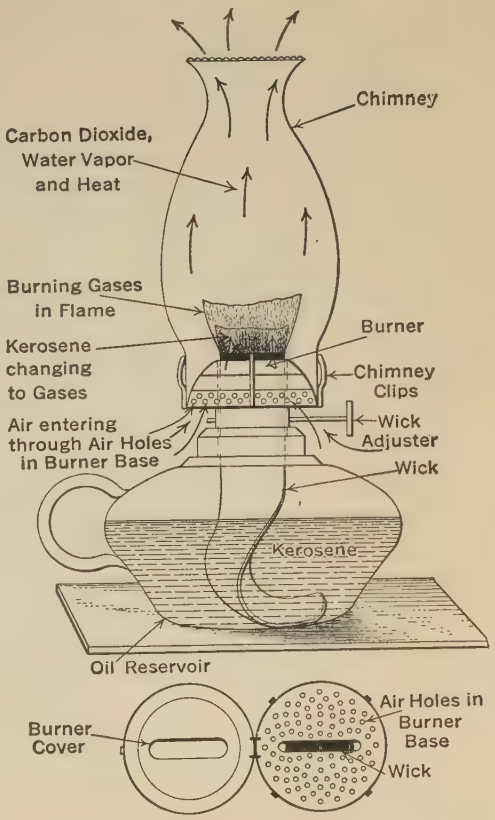


FIGURE 139. — THE COMMON KEROSENE LAMP. Explain the use of each part labeled. How does the lamp work?

233. Kerosene Lamp Improvements. — Although many rural and village homes must still use the kerosene lamp,

there is no need of having poor illumination with this form of light. A study of Figure 139 will show you the parts of the kerosene lamp and their uses. Why is the Rochester burner better than the ordinary flat-wick lamp? Study Figure 140 and explain it.

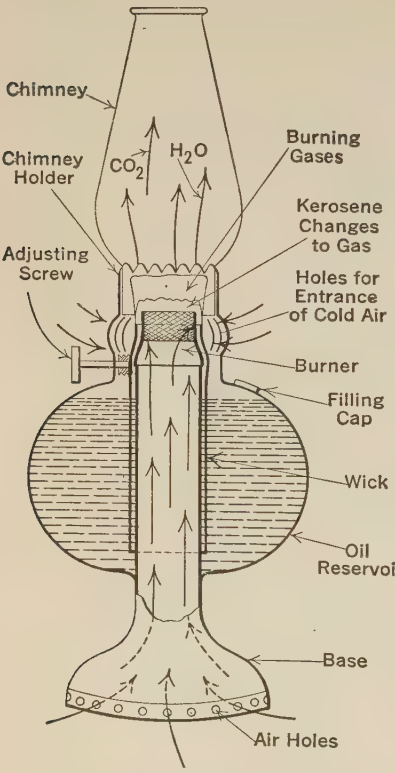


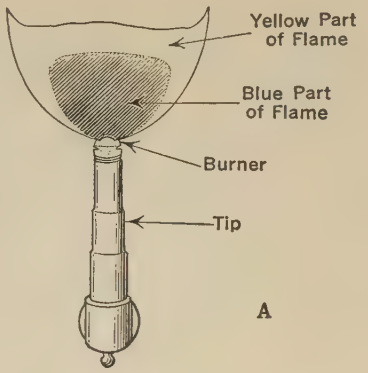
FIGURE 140. — THE ROCHESTER BURNER.

Tell the use of each part labeled. What is the advantage of having air enter at two different points?

234. The Gas Flame. — You are no doubt familiar with the common gas jet and the Welsbach mantle. How do you suppose that the gas jet gives light and the mantle increases this light?

Suggested Experiment. — Secure a Bunsen burner, a gas jet, and a Welsbach burner or mantle. Light the Bunsen burner. Note the flame. By opening and closing the opening, increase or decrease the amount of light given off. Light a fishtail gas jet (Fig. 141, A). Note the flame. Compare with the Bunsen burner flame. Note the flatness of the flame. Attach the mantle to the gas jet, Figure 141, **B**, and "burn off" the mantle by touching a match to its lower end. Turn on the gas and light the mantle. Note the brilliancy of the flame. What is the color of the Bunsen flame? What causes the changes in it? Is there hydrogen in the flame? Explain. Where does the flame get its oxygen? When do you get the most light? Explain. Explain why you get the least light

with the most oxygen. Is a Bunsen burner used primarily for light or for heat? Why is the slit tip put in the gas jet? What is the advantage of a flat thin flame? Where is it the hottest? the lightest? Explain. Why is this flame so much more brilliant than a Bunsen flame? Can much oxygen reach it? How? Explain. What is the effect of the mantle on the flame? Does the mantle burn? Do you suppose as much gas is used with a mantle as without a mantle? Explain. No light is given by the burning gas inside the mantle. It is the incandescence (ĭn'kăn-dĕs'ĕns) [1] of the coating on the mantle which gives the light. How can the light of a gas flame be increased? Explain. What advantages has the mantle over the open flame or fishtail jet?



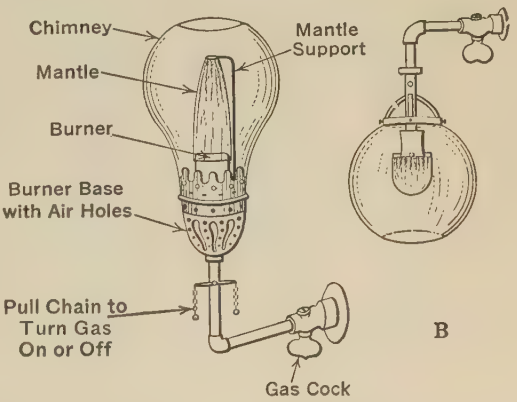


FIGURE 141. — THE FISHTAIL GAS FLAME AND WELSBACH BURNERS.

Explain the use of each part labeled. Why is the inverted mantle to be preferred?

235. The Gas Mantle. — The chief objection to the open or fishtail gas light is the large area of non-luminous blue flame at its center. It is also an unsteady light. The invention of the Welsbach mantle solved these difficulties very completely. The mantle is composed of a mineral substance called *thorium*, which

[1] Incandescence: glowing.

becomes incandescent, due to the intense heat of the gas flame. The carbon and hydrogen in the gas are consumed just as they reach the sides of the mantle. Thus, there is no smoke or flicker, but rather a steady, intense light with a maximum of convenience and a minimum of expense. Name one difficulty in using the mantle. Study Figure 141, B and explain it.

236. How Does an Electric Bulb Give Light? — You are quite familiar with the general appearance of an electric bulb, but did you ever examine one carefully to see how it was made?

Suggested Experiment. — Secure a dry cell battery, a three-inch length of fine copper wire, a three-inch length of German silver wire, and a flashlight bulb. Connect the positive and negative poles of the dry cell with the piece of copper wire. In a moment feel of the wire. Replace this copper wire with the German silver wire. Note results. Compare with the copper wire. Connect the terminal or contact point of the small electric bulb with the poles of the dry cell. Note the result. Compare with the other two wires. What caused the copper wire to become hot? Why did the German silver wire become red hot? Why did the electric bulb wire become incandescent? Which offered the most resistance to the electric current? Which offered the least resistance? Explain. What two important conditions must be met before light can be produced by an electric current? Examine the ordinary electric light bulb of 40-watt capacity. Note its construction and the uses of its parts. How does an incandescent electric bulb give light? Give proofs and full explanations. Give full results in your Science Discovery Book.

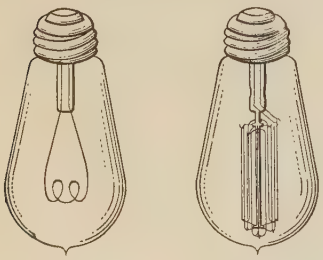


FIGURE 142. — TWO KINDS OF INCANDESCENT ELECTRIC BULBS.

Which gives more light? Why?

237. The Tungsten Light. — To Thomas Edison we owe the origin of the electric light. He used years of careful experimentation in seeking a proper filament to carry the cur-

rent; a filament that would give a maximum amount of light without burning out. The principle of the incandescent light is the resistance of a fine filament to an electric current. The smaller the wire, the greater the resistance and the brighter the light. With the use of tungsten as a filament, a brilliant white light is produced and it has now taken its place as the best light for all-round illumination and

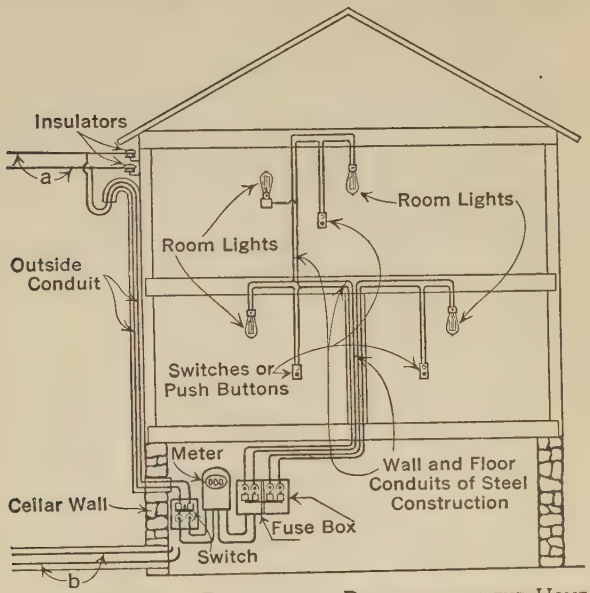


FIGURE 143. — HOW ELECTRICITY IS DISTRIBUTED IN THE HOME.
Explain the use of each part labeled.

intensive work of all kinds. Study the diagrams (Fig. 142) of the two kinds of bulbs and explain each. The nitrogen bulb is a still later product. Why is it desirable?

238. Electric Wiring in the Home. — Certain substances, such as copper, steel, and aluminum, are excellent substances for carrying currents of electricity and are called *conductors*. The wires entering and carrying current to every outlet in the home are made of copper and are covered with rubber,

asbestos, or other materials to prevent loss of current, short circuiting, and fires (Fig. 143). Explain. These coverings act as *insulators*.[1] Other insulators are bakelite and porcelain. In modern house wiring, metal pipe conduits (kŏn'dĭts)[2] are used for the wires, thus absolutely preventing any possibility of fires, provided the conduits are perfect in construction.

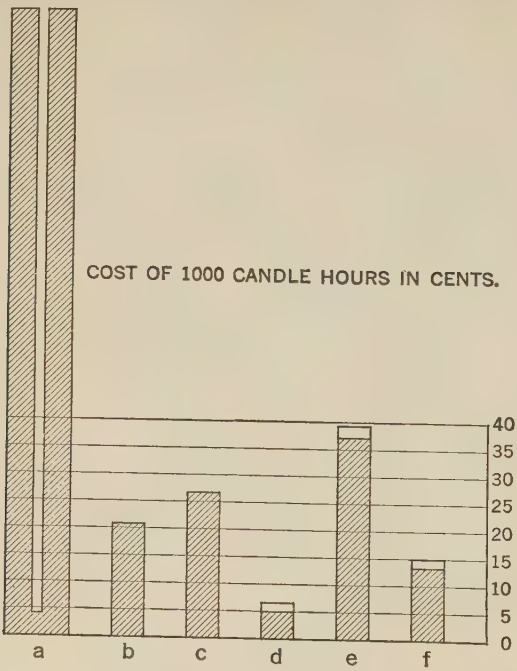


FIGURE 144. — THE COSTS OF USING DIFFERENT KINDS OF LIGHT.

a, candle; **b**, kerosene lamp; **c**, gas (open flame); **d**, gas mantle; **e**, carbon electric bulb; **f**, tungsten electric bulb.

Based upon cost of candles at 12 cents a pound, kerosene at 15 cents a gallon, gas at $1.00 for 1000 cu. ft., and electricity at 10 cents a kilowatt-hour. The blank portions of columns **d**, **e**, and **f** represent cost of bulbs and mantles. Which is the cheapest light? Which gives the most light? Which is the most convenient light?

[1] Insulators: non-conducting substances.

[2] Conduits: channels or pipes for carrying electric wires.

239. Relative Costs of Light. — Cost is not the only factor which should determine the kind of light to be used. Convenience and brilliancy enter into the problem as well. All improvements in lights aim to reduce the cost and to increase their brilliancy. On this basis the poorest light is the most expensive. A study of Figure 144 will show the relative costs of several kinds of lights. Study them and answer questions upon them. As Figure 144 demonstrates, in cities and large towns the inverted mantle cannot be excelled for cheapness and brilliancy. Because of its convenience and reliability the Mazda electric light is commonly used in the home.

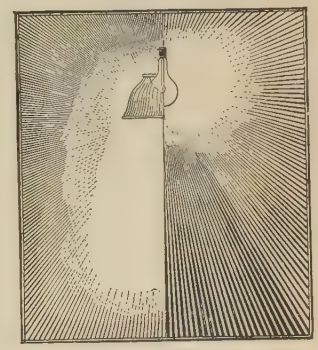


FIGURE 145. — DIRECT LIGHTING.

Excellent for bathrooms and kitchens. Why? What is the advantage of the fluted glass shade?

240. Direct Lighting. — Direct light is always best for close work in a room. Of course the rest of the room will be in a dim light, for the protection of the eyes and the concentration of the light rays demands an opaque shade to throw the light directly down. Study Figure 145 and determine how the light rays travel to the eye from their source. Account for the direction of the light rays. Explain the shadow above the shade in Figure 146, A and the lighted area below it.

241. Semi-direct Lighting. — The diagram on page 278 (Fig. 146) shows this form of lighting. In what rooms is this form best used? How does this differ from the direct system? What is lost in this type? What is gained? Would the color scheme of your living or dining room have anything to do with the value of this light? Explain. What is meant by semi-direct lighting?

242. Indirect Lighting. — This type of lighting is often considered the best for general illumination in the home. Study Figure 146, B and give two reasons why you think this

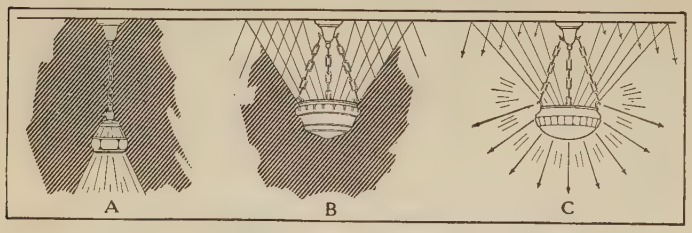


FIGURE 146. — THREE FORMS OF LIGHT DISTRIBUTION.

A, direct lighting. How does this differ from that shown in Figure 145? **B**, indirect lighting. How is the room lighted here? What is the disadvantage of this method? **C**, semi-indirect lighting. How does this differ from **B**? This is valuable in dining and living rooms and for halls and schools. The modern tendency is to use side units in the home.

may be so. Give reasons for the direction and turns of the light lines. What color scheme should be used in the dining room to insure the best illumination with this type of light? Many libraries, churches, and public buildings are

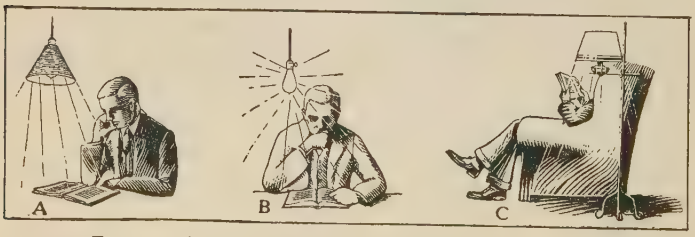


FIGURE 147. — TYPES OF ILLUMINATION FOR STUDYING.

Compare these pictures and tell which is best for the eyes. Give reason for your answer. Which type do you use each night? If it is wrong correct it at once.

lighted in this way. The lights are nearly always invisible, and the softness of the illumination is pleasing and restful to the eyes. For intense or fine work, however, such a type

of lighting is far from best. Explain. Study the three drawings in Figure 147.

243. Shade Colors. — The color of the shade is a most important item in illumination. In the reading lamp a bright green (signal green No. 2) shade allows about 19% of the light to pass upwards through it. This helps to light the room as well. For softer effects in a living room canary-colored shades allow 82% of the light to pass into the room. Ecru or light buff shades allow about 70% of the light to pass into the room. Both types of shade are most pleasing.

For the kitchen and bathrooms, the clear, white glass shade is the best. This allows almost 100% of the light to pass through. Explain the use of the fluted surface. The pure white shade is often used in the semi-direct lighting of the dining room. This gives about 90% illumination, and when softened by the use of about two 40-watt bulbs provides an effective and pleasing illumination. Where the home is electrically lighted, the changing of bulbs which have dimmed because of the gradual burning away of the filament should not be neglected.

244. Wall Colors of the Home. — The lighter the wall colors, the less artificial light need be used. Explain. A light buff wall will give the best illumination effects. What color should one paint or paper the kitchen? the bathroom? What should be the general color scheme of a room facing the north? the south? It has been found that light cream paint diffuses 52% of all the light coming to it and cream paper 56%. Very light green paint diffuses 45% of the light, while brown paper gives off but 13%, dark green 5% and red about 12%.

It is evident, then, that your selection of wall coloring is a most important point in the comfort, cheerfulness, and efficiency of your home. The proper choice will safeguard these factors of home life because eyes will be free from strain and nerves will not be disturbed by glaring or inharmonious combinations. How would the decorations be of any importance in the illumination of your home? Explain fully.

REVIEW OUTLINE

1. The Importance of Light: (1) Gives us power to see; (2) causes growth in plants; (3) gives us fuels.
2. The Nature of Light: (1) Vibration of ether; (2) a form of energy; (3) travels in straight lines.
3. Sources of Light: (1) The sun; (2) oxidation of fuels; (3) electricity. Speed of light rays.
4. Why Things Are Visible. Direct and reflected light rays.
5. Shadows. How caused. Parts of a shadow. Avoidance of shadows in the home.
6. Control of Light by: (1) Reflection (mirrors); (2) refraction (prisms and lenses); (3) diffusion (ceilings); (4) translucent glass.
7. Reflection of Light in the Home by: (1) White woodwork; (2) polished furniture; (3) glassware; (4) bright ceilings and hangings; (5) mirrors.
8. Diffusion of Light in the Home by: Light colored and roughened ceilings.
9. Refraction of Light in the Home by: (1) Aquaria; (2) prisms; (3) brilliants.
10. Color in the Home: Nature; dependence upon light; cause of color variations. Importance of having pleasing colors in the home.
11. The Use and Importance of Lenses: Kinds; effects upon light rays; uses.
12. The Camera: Parts; uses; methods of taking pictures (negative and positive).
13. The Human Eye: Parts and their functions; light control by the eye. Eye defects; detection of defects; correction of defects. Care of eyes. Motion pictures; construction and principle.
14. Artificial Light: How produced by candle, oil lamp, gas flame, electricity.
15. Candle Power in the Home: (1) The unit of illumination; (2) amount of light needed for different rooms and work; (3) light improvements (kinds).
16. Electrical Wiring in the Home: (1) Parts; (2) principle and use of insulators and conduits.
17. Kinds and Methods of Home Illumination: (1) Direct; (2) semi-direct; (3) indirect. Costs of different systems of lighting.
18. Importance of proper selection of colors of shades, hangings, and walls.

SUMMARY

A lightless world would be a sightless world. Work, pleasure, and culture are possible through light. *Light is a form of energy* brought to us by vibrations of the *ether*. It travels in *straight lines* and because of this, opaque objects cast shadows. *Shadows* are common in the home, where they should be avoided as much as possible.

Light rays are controlled by *reflecting* them, *refracting* them, *absorbing* them, and *diffusing* them. To secure such control mirrors, prisms, lenses, and roughened surfaces are used. Light produces colors because some of its component rays are absorbed more readily than others. A color scheme for all interior decorations is important.

Lenses are used to bend light rays to any desired angle so as to enlarge small objects or bring to a proper focus light reflected from some object to a defective eye. The microscope, stereopticon lantern, the reading glass, the hand lens, the moving picture projector, and ordinary nose glasses are all machines for the bending of light rays. The camera and eye themselves both depend upon the double convex lens for their usefulness and both are built upon the same principle. Eye defects should be corrected with glasses. Nothing is more important than the hygiene of the eye.

The rotation of the earth necessitates *artificial light*. The history of artificial lighting has been the development of devices of increasing light through the use of the *tallow dip*, *candle*, *lamp*, *gas flame*, *mantle*, and *electric bulb*. Improved lights at once developed the problem of proper illumination. The problem has been solved by the development of the *direct*, *indirect*, and *semi-indirect* lighting by means of specially constructed fixtures. To aid in proper illumination, to give pleasing effects, and to prevent injury to the eyes, the proper *coloring* of *shades*, *ceilings*, and *hangings* now demands much thought and attention.

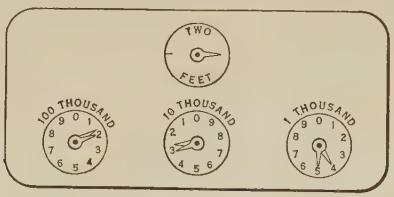
Remember that:

1. Light is a form of energy brought to us by vibrations of the ether.
2. Most objects are visible to us by reflected light.
3. Light rays can be controlled and directed by the use of prisms, lenses, and different kinds of surfaces.
4. The human eye as the organ of sight must receive special care to protect it from too much or too little light.
5. By modern devices, artificial light can be produced and properly distributed so that the human eye is not injured.

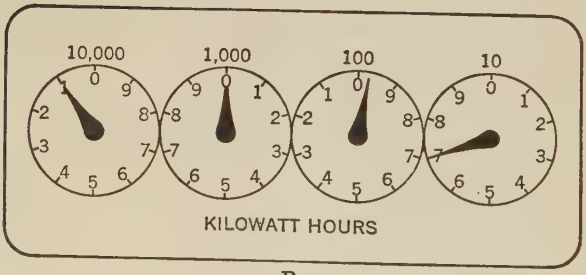
SPECIAL PROBLEM

Learn how to read the gas and electric light meters.

Suggestions: Observe the dials on both kinds of meters. Note the unit of measure on each dial. Both are read from the extreme left index to the extreme right index with the top unit of the gas meter indicating two units (Fig. 148).



A



B

FIGURE 148. — METERS.

A, gas meter; B, electric meter. How are these meters alike? How do they differ?

When the hand on any index points to any spot between two units the lower figure is to be taken as the basis for computation. The numbers on the dials give you the correct amount of cubic feet of gas or kilowatt hours used. Read your gas meter at home and try to find out the exact number of cubic feet of gas you have used to date. Construct several dials on paper and at random move the hands about the dials. Now try to read your meter dials. This gives good practice.

Secure your last gas bill and note the number of feet used at the time the meter was read. Find out what your gas bill would be to-day. See if you are using the average amount of gas. If not, try to account for the difference.

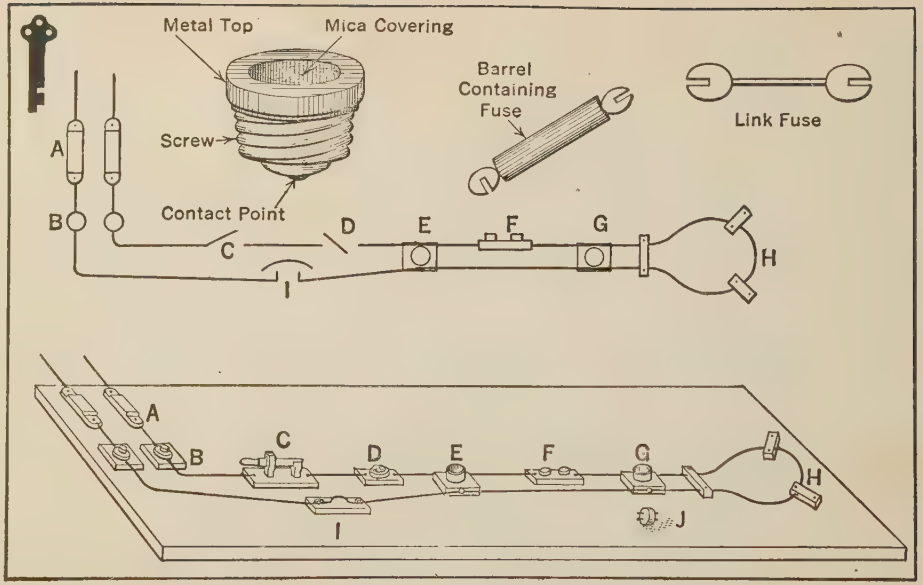
Read your electric meter the same way, computing the cost in kilowatt hours to date. Try to account for possible causes in increase of electric bills. Which kind of light is cheapest in the long run? Explain.

THOUGHT QUESTIONS

1. Everybody casts a shadow. Why?
2. Sun shadows cover a larger area at one time of the day than at another. When are they longest? Explain.
3. Can a piece of glass cast a shadow? Explain.
4. The walls of courts and air shafts are often painted white. Why?
5. Many people form the habit of reading on trains. Is this a good habit? Explain fully.
6. Why do small fish often look large in an aquarium?
7. What is the economic advantage of packing olives or other fruits in glass jars?
8. Why should seats be arranged in a schoolroom to allow the light always to come from the left?
9. What light is injurious for studying purposes?
10. How can rooms be well lighted by sunlight even though the sun does not shine directly into the room?
11. How will a tablecloth make a room look brighter?
12. Explain fully just how a gas flame and an electric bulb make light.
13. What makes the moon shine?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Burns. Great Inventions. Harper and Bros.
Davis. Making Your Camera Pay. McBride Co.
Eastman Kodak Company. How To Make Good Pictures.
Fish and Fisher. How To Live. Funk and Wagnalls Co.
Gibson. Romance of Modern Photography. J. B. Lippincott Co.
Lubschez. Story of the Motion Picture. Van Nostrand Co.
Luckiesh. Lighting the Home. Century Co.
Lynde. Physics of the Household. The Macmillan Co.
Tappan. Wonders of Science. Houghton Mifflin Co.



KEY PICTURE 10. — COMMON ELECTRICAL CONNECTIONS AND CONTROLS.

The whole of Chapter X is based upon this picture. **A**, cartridge fuses; **B**, plug fuses; **C**, knife switch; **D**, snap switch; **E**, lamp socket; **F**, flush switch; **G**, lamp socket; **H**, nichrome or German silver wire; **I**, fuse gap. Become familiar with the use of these parts.

CHAPTER X

MAGNETISM AND THE WORK OF ELECTRICITY

I'm the spirit of light and love,
To my unseen hands, 'tis given
To pencil the ambient clouds above,
And polish the stars of heaven.
I scatter the golden rays of fire
On the horizon far below,
And deck the skies where storms expire
With my red and dazzling glow.
—"The Song of Lightning": George W. Cutter.

Do You Know How a Compass Works?

Why does its needle point north? How do you suppose that objects become magnets? Would you like to know how to magnetize an object? The motorman calls electricity "juice." What would you call it? How can one "make" electricity? How can you make it flow? Would you like to know how it can be controlled and made to do work? You can work any number of experiments which will give you much information on the whole subject of electricity.

Some Practical Questions:

1. Why may one get a severe shock if his hands are wet when he touches a wire through which an electric current is passing?
2. How are magnets put to practical use in everyday life?
3. What is meant by a short circuit and why are short circuits dangerous?
4. Why are glass insulators used on telephone poles to carry the wires?
5. Why may a compass not work in or near a power house?

Home Problem. — Watch the play of lightning during a thunder storm and note the different types of lightning flashes. Follow the progress of the storm by noting the time elapsing between the lightning flash and the clap of thunder, counting four seconds to the mile.

Field Problem. — Watch the men who lay and adjust the electric light wires and cables in your town or city. Ask them questions about the construction and working of the electric light system and report your findings to the class.

1. Magnets and Their Use

245. The Compass. — Every sea captain would be lost without a compass. This simple instrument has saved thousands of lives both on land and sea. Everyone who walks much or takes long tramps across country should carry one of these small and wonderful instruments (Fig. 149). Just how a magnetic needle works can be shown in a very simple experiment which you can easily work at home.

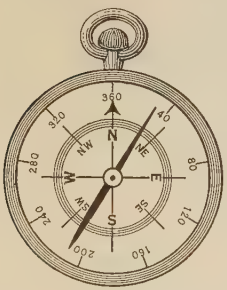


Figure 149. — A Simple Compass.

Note the points of the compass. Where is the magnetic north indicated? How would the needle indicate north? southeast? How could you use a compass?

Suggested Experiment. — Get a horseshoe magnet and a small compass.

A. Place the compass flat upon the table. Watch the action of the needle. Revolve the dial until the letter "N" is beneath the point of the needle.

B. Hold the points of the magnet directly over the compass. Revolve the magnet slowly and watch the compass needle. Note if any particular end of the magnet attracts the north pole end of the needle. Now hold the end of the magnet which attracts the north pole of the needle near the south pole of the needle. Watch results. Finally hold the other end of the magnet near the south pole of the needle. Note result. Which is the north pole of the needle? Which is the south pole? Which is the north pole of the magnet? Is this marked? What happens when the north pole of the magnet is placed near the north pole of the compass needle? near its south pole? What is the effect of the magnet upon the compass needle? Now hold your jack-knife blade near

the compass. Why should one never try to use a compass when some metal such as a jack-knife is close to the compass?

246. How Objects Become Magnets. — Some things, like the earth, are natural magnets; others are magnetized by artificial means as in the case of a needle, which one can magnetize with a magnet. Any bit of steel can be made into a magnet by rubbing it against a lodestone, a kind of ore found in abundance in Asia Minor. If two magnets are placed near each other, the north poles of each magnet will repel each other as will also the south poles, but the north and south poles of two magnets will attract each other. *Thus, like magnetic poles always repel and unlike magnetic poles always attract each other.* Soft iron easily becomes magnetized but soon loses its magnetism. Steel is harder to magnetize, but it retains its magnetism a long time.

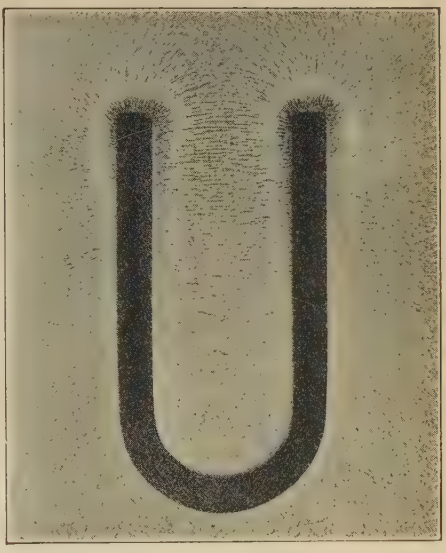


FIGURE 150. — LINES OF FORCE ABOUT A HORSESHOE MAGNET.
Note how they cross from pole to pole.

247. How a Magnet Works. — The very fact that the magnet caused the needle to move means that work was done. Work requires force. Where was this force hiding? How did it act?

Suggested Experiment. — Get a sheet of stiff writing paper about four inches square, some iron filings, and a horseshoe magnet.

Pour some of the iron filings upon the center of the paper. Holding the paper in one hand by its edge, place the poles of the magnet under the paper, touching it in the vicinity of the filings. Note what happens. Do the filings move? In any particular direction? Do they form any particular pattern about the poles of the magnet? Do the filings form an indistinct line between the poles? Write out the conclusion in full in your Science Discovery Book. This experiment will be valuable to you later.

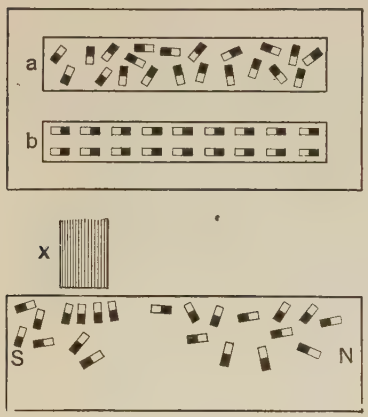


FIGURE 151. — MAGNETIZED AND DEMAGNETIZED STEEL.

At **b** the molecules are in alignment, all like poles pointing the same way. Here we have a magnet. In **a** the steel has lost its magnetic power. What has happened? In the lower picture what effect does a magnet (**x**) have on the molecules of a demagnetized piece of steel?

248. Lines of Force. — Your experiment showed you that there are *lines of force* (Fig. 150) between the poles of the magnet because the filings were forced to arrange themselves along these lines. We call the region of the lines of force the *magnetic field* but the power of this field naturally becomes less and less as objects are moved away from it. If a magnet is heated or suddenly pounded, its lines of force disappear and it loses its power as a magnet. The molecules have become thrown out of alignment (Fig. 151).

2. How Electricity May Be Generated

249. A Simple Way of Producing Electricity. — Hundreds of years ago the Greeks discovered that if certain substances are rubbed together, they then have the power of attracting certain other objects. One of these substances which they used was amber, the Greek word for which is "electros,"

hence our word "electricity." How can you in the class room make electricity? This is extremely easy.

250. Frictional Electricity. — If one will rub a rubber comb with a flannel cloth and then bring the end of the comb near a faucet or chandelier, a spark of electricity may be seen and a snapping sound will be heard. Rubbing a cat's back in the dark on a cold night will give the same result. These are *electric charges* or *frictional electricity.* (Fig. 152.)

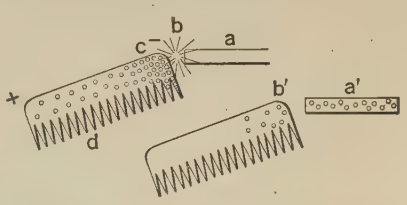


FIGURE 152. — FRICTIONAL ELECTRICITY.

a, metal bar; b, electric flash; c, electrons crowded at end of comb; d, comb. In which direction are the electrons going? Why? a', metal bar now holds electrons coming from comb; b', a few electrons which did not jump. Why?

251. What Is Electricity? — No one knows just exactly what it is, but we know a good many things about it through observing how it acts or what it does. We cause it to do all sorts of useful work for us such as propelling cars, automobiles, and boats; furnishing light; ringing bells; and carrying messages.

A thimbleful of air contains 6,000,000,000,000,000,000 (six quintillions) of molecules. Molecules are composed of smaller bodies called atoms. An atom consists, according to recent study, of a nucleus of *positive* electricity, called the *proton*, surrounded by units of *negative* electricity called *electrons*. These electrons move about the nucleus much as our earth moves about the sun, and some of them travel at the rate of some 90,000 miles a second. These electrons are what we know as electricity.

252. Positive and Negative Charges of Electricity. — If the total negative charge of the electrons of the atom equals the positive charge of the proton, the atom is unelectrified. If the negative charge is decreased by a loss of electrons, the atom is said to be *positively charged.* If the

negative charge is increased by an addition of electrons, the atom is said to be *negatively charged.* Objects with opposite charges attract each other; objects with like charges repel each other. If the difference between the charges on oppositely charged objects is great enough, a spark will occur when they are brought close together.

253. Frictional and Current Electricity. — Frictional electricity was the only kind of electricity that any one knew anything about until around the year 1830. It can do little valuable work. It destroys, but does not build. There must be a steady stream of electrons through substances to do work. If electrons are set free from the atoms and move along a conductor, they form an *electric current.* When current electricity was discovered and controlled, work could be done. Frictional electricity has high *voltage* (pressure) but low *amperage* (rate of flow). Current electricity has not only a high voltage but also a good amperage and for that reason is very useful in the world's work.

3. How Electricity Can Be Made to Do Work

254. Common Storage Cells and Their Use. — In this day of automobiles and radio almost everybody knows something about the storage cell and its importance (Fig. 153). It is essential in the radio to heat the tube filaments and in the automobile in starting, lighting, and in the ignition system (to fire the spark plugs). How can a simple storage cell be made?

Demonstration 27 (Teacher's Demonstration): *Problem: How can a storage cell be made and used to do work?*

Materials: Two pieces of sheet lead, three by six inches in size, with a hole near one end of each; two pieces of copper wire, each one foot long and connected at one end to one of the holes in the lead sheets; a glass jar; sulphuric acid; an electric bell; and four dry cells.

Method: A. Pour three or four tumblers of water into the glass jar. Now slowly pour $\frac{1}{4}$ tumbler of sulphuric acid into the water.

Caution: Keep this acid off your hands and clothes. Always be sure that you pour the acid slowly into the water and not the water into the acid. Lower the plates into the jar. You now have a storage cell.

B. Connect the four dry cells in series — from the carbon (center post) of one to the zinc (outside post) of another. Attach the wires from the lead plates to the two free battery terminals. You have now formed a *circuit* and electricity is passing into the cell.

C. Let the cell charge for a few minutes. Disconnect the dry cell battery and connect the storage cell to the binding posts of the bell.

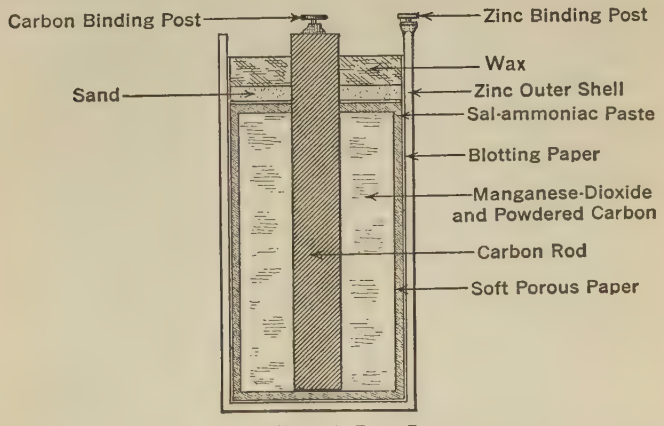


FIGURE 153. — A DRY CELL.

Find an old cell, take it apart, and find each part here indicated. With the help of your teacher find out the use of each part here labeled. What is a common use of dry cells?

Observations: What do you notice collecting on each plate? These are hydrogen and oxygen bubbles. What forms the bridge to carry the current across in the jar? Where is the electricity being stored? What makes the bell ring? Where did this energy come from? Where was it stored? Examine the plates. Note the brown covering of one plate. This is lead dioxide. It is a compound of lead and oxygen. Where did each come from? What happens to these elements in the storing process?

Conclusion: How is the storage cell made? How does it do work?

255. Electroplating. — Plating metals with silver or similar metals keeps them from rusting and makes

them look much better. Plating a cheap metal with a fine metal is cheaper than buying a solid article of fine metal. Thus we have plated gold watches and plated knives, forks, and spoons. How is plating done with an electric current?

Demonstration 28: *Problem: How may one copper plate a piece of metal?*

Materials: One pound of copper sulphate; a glass jar; water; a battery of two dry cells; a carbon rod from an old dry cell; a strip of copper 2×6 inches; a wire nail; a small iron spoon, and sandpaper.

Method: Put one quart of water in the jar and dissolve in this a half-pound of the copper sulphate. Let stand over night. Pour off about two-thirds of the solution into a clean cell jar. Connect the carbon rod and the copper strip with the two dry cells set up in parallel — carbon to carbon; zinc to zinc. (Be sure to get the carbon rod connected with a zinc binding post and the copper strip to a carbon binding post.)

Now without letting them touch, lower the carbon rod and the copper strip into the copper sulphate solution. Beginning at the carbon of the battery, the current runs through the connecting wire to the copper strip; through the solution to the carbon rod; through the connecting wire to the zinc of the cells; and back to the carbon of the battery again.

Observations: After several minutes examine the carbon rod. What has happened to it? The current takes the copper out from the solution and puts it where? The solution then dissolves more copper out from the copper strip. This uses up the copper strip. How is the solution changed every moment?

Reverse the wires, attaching carbon to carbon pole and copper to zinc pole. Immerse the carbon and copper and see what happens. Where is the copper now? Explain what has happened. How does plating depend upon the direction of the electric current? Sandpaper the nail and the iron spoon. Attach them in the circuit and copper plate them.

Conclusion: Explain how copper plating is done.

256. Importance of Electroplating. — The only difference between copper plating and silver, nickel, gold, and tin plating is (1) in the kind of strip (plating material) to be dissolved by the electric current and (2) the kind of solution used to carry the current from the plating material to the other pole. The principle is always the same. The metal used

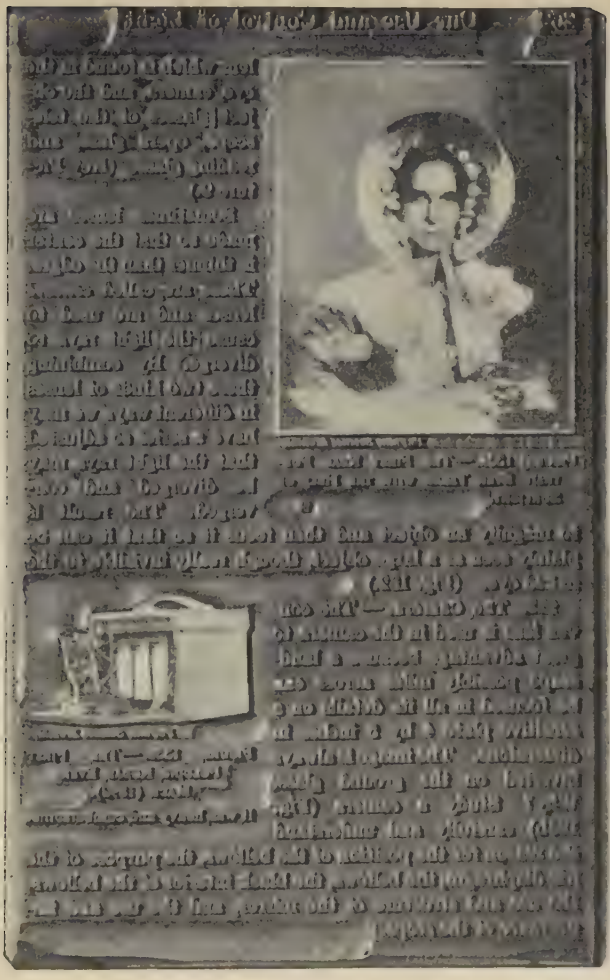


FIGURE 154. — THE COPPER PLATE USED TO PRINT PAGE 262 OF THIS BOOK.
For this reproduction the half-tones (pictures) of the plate were dusted with a white powder to bring out the images better.

for the plating and the solution must be alike in nature. All gold, silver, and copper plating is done in this manner.

Most magazines and books are printed from copper plates made by the electroplating method (Fig. 154). Thousands upon thousands of books can be printed from these plates while the original type can be distributed or, if it was linotyped or monotyped, can be melted and the metal used again. Electroplating makes possible the enormous number of books and magazines. It is easy to see that the discovery of the method of causing an electric current by the use of a battery has been a great factor in our present education and the industry of the world. Explain this.

257. The Importance of Current Electricity. — Batteries may give us spot lights, ring our door bells, carry our telephone and telegraphic messages, make the radio possible, and help move our automobiles. But when we come to the matter of steady lighting, heating, and work, we must have a continuous current of electricity of a constant and even strength and amount. This can be obtained only by current electricity produced by a dynamo in a power house.

Power house electricity runs our trolley cars, many of our railroads, some of our steamships, and many of our industrial plants. Most of the lighting of our towns and cities depends upon the same source.

4. How Electricity Can Be Controlled in the Home

258. How Electric Currents Are Controlled. — Copper is an excellent conductor of electricity because the electrons can flow easily along it. But there must be some method of controlling this current, shutting it off or turning it on when desired, and there must be a means of protecting the building from an overload of current. Too much current may melt the wires and cause a fire. What are the pieces of apparatus used to make and control an electric current?

Demonstration 29: *Problem: How can an electric circuit be set up and adjusted for proper control?*

Materials: 10 or 15 feet of No. 24 insulated electric wire; a flush switch; a snap switch; a knife switch (Key Picture 10); two 15-ampere cartridge fuses; two 10-ampere plug fuses; about 4 inches of 4-ampere fuse wire; two lamp sockets; one 15-watt and one 30-watt incandescent bulb; several sheets of asbestos; about 10 feet of No. 30 nichrome resistance wire or 30 feet of No. 30 German silver wire; a pine or spruce board $\frac{1}{2}$ inch thick, 10 inches wide, and about 6 feet long; one dozen porcelain wire cleats; some shingle nails; and one cartridge fuse block to be used as a fuse gap. (See Key Picture 10.)

Method: Set the board on edge and support it with a firm base or fasten to the wall near an electric light socket (outlet). Cover one end surface of the board with the asbestos sheets. Over this asbestos fasten the nichrome or other uninsulated wire. At intervals on the board fasten the other parts of the apparatus as shown in Key Picture 10. Bridge the fuse gap with No. 24 wire. Connect one binding post of each of the two cartridge fuse blocks with the electric light socket by a piece of the No. 24 insulated wire, connect the other ends of the wires to an ordinary plug, and put the plug into the socket. With no power house current 4 to 6 dry cells connected in parallel with small decorative bulbs and sockets may be used. When all parts are securely fastened, place the two bulbs in the sockets and close all the switches.

Observations: What happens? Is the circuit complete? Now open the knife switch. What happens? Is the circuit complete?

Conclusion: Explain now how an electric circuit is set up and how tested to see if the circuit is complete. This is the most important demonstration of this whole chapter. Write it out in your Science Discovery Book with great care.

259. Making and Breaking an Electric Circuit. — The flow of electricity around a circuit might be compared to the flow of water in a circular sluiceway or irrigation ditch. If, in the case of the circular water sluiceway, you opened a hole in the side, the water would soon all flow away, leaving the ditch empty, or if you put a partition across the ditch, you would stop the flow or break the current of water. It would not be continuous. What effect would a partition have on the volume of water on either side of it?

Just so in the electric circuit, a wire lying across your circuit will carry off your electricity. If the wires are not insulated, much of the electricity will be lost. Or if you open up a place in the circuit making an air gap, the electricity cannot jump this gap and you have broken the circuit. Just how this is done can be well shown with your apparatus.

Suggested Experiment. — Close the circuit (if it is not already closed) and see that the bulbs are burning. Now lift the knife blade of the first switch. Note the space (air) between the blade and the slot. Why do the lights go out? Of what advantage is this arrangement in a school? in a home? Now close the switch and note the effect. Of what are the switch slot and blade made? Explain.

With the circuit closed, unscrew the smaller one of the bulbs. What happens? What have you done? How does this affect the other lamp? If a switch happened to be out of order, how could you control your lights?

Next turn off the snap switch. What happens? Where are these switches mostly used? Are they used on bulbs? Take apart a snap switch and see just how it is constructed and how it works. Be able to explain this to the class.

Finally, examine the flush switch. With the other switches closed press one of the buttons of the flush switch and note what happens. Where are these switches commonly used? What is the advantage of these switches over the other types? Take the back off one of these flush switches and see how it is made and how it works. Examine the switches in your school, your church, and your home. Note where each type is located, determine why it is used where you find it, in preference to other types. Trace the circuit in your own home and be able to tell how it is insulated and how it is controlled. Make note in your Science Discovery Book of any important facts you have learned here.

260. Importance of Fuses in a Circuit. — It is not an uncommon experience to have your home put in total darkness by someone who is repairing a socket or connection in an electric iron or heater. The darkness is the result of the blowing out of a fuse somewhere on the line. Such fuses are frequently (almost always) found in a wall box in the cellar. They are generally 10-ampere plug fuses and two

or three extra ones should always be kept on hand for just such emergencies. It is well to know the construction of fuses and how they are inserted, for it may save you the trouble and expense of securing an electrician. (See Key Picture 10.) To learn something practical about fuses a simple demonstration may be worked as follows:

Demonstration 30: *Problem: How do fuses work and why are they important?*

Materials: The same as in Demonstration 29; also a wooden plug, to fit one of the lamp sockets, through which have been driven two wire nails in such a way as to have them touch the contact points at the bottom and side of the socket and have about $\frac{1}{2}$ inch or so of the nails sticking out of the plug towards you.

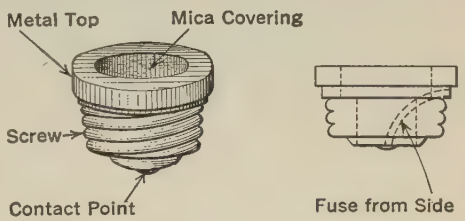


FIGURE 155. — THE PLUG FUSE.

What is the use of the mica? the contact point? the fuse wire?

Method: Place the 4-ampere fuse wire across the fuse gap between the two binding posts and fasten it in securely. *Caution: Before doing this, be sure that all the switches on the upper wire are open!* Now put the plug in a socket so that the nails will touch the contact points. See that there is no lamp in the other socket. Now shut the switches on the upper line. Does anything happen? Can you explain this?

Open the switches. Renew the fuse wire. Remove the insulation from the ends of a 3 ft. piece of wire. Close switches. Touch one end of this wire to one of the nails in the plug and the other end to a water pipe or radiator. What happens? Try the other nail in the same way. What happens?

With the switches open, stretch another piece of fuse wire in the fuse gap. Touch the nail that worked in the preceding paragraph with the central contact point of the electric bulb, and the side contact of the bulb with the wire from the radiator. Close the switches. What happens? Explain.

NOTE. — A 4-ampere fuse wire will carry a little more current than 4 amperes without melting. Your 10- and 15-ampere plugs and fuses will also carry a little more than indicated.

What would happen if you put a heavy copper wire across the fuse gap and then sent a current greater than 10 amperes through the line? Suppose you put a 20-ampere plug in the fuse sockets and ran a 40-ampere current through your line. What would happen then?

Observations: Write out in full in your Science Discovery Book what you saw happen.

Conclusion: How does a fuse work? Of what value is it on a line?

Practical Applications: Observe your plug fuse box at home. Note the fuses. How many circuits have you in the house? If a fuse blows, learn how to find out which one has blown and how to put a new one in.

Fuse wire is composed of a very soft metal and has a very low melting point. A lighted match, held close to it, melts it. It can carry a certain strength of current but its resistance to any heavier load is so great that it gets hot and melts. The fuse is blown, so breaking the circuit. You may have caused a fuse to blow by "short circuiting"[1] the current. In doing so, you gave the current an easy path to follow by greatly reducing the resistance. If this 4-ampere fuse had not blown out, the more expensive plug or cartridge fuses would have blown. If no fuses had been placed in the line in which you caused a short circuit, the copper wires in the wall of the building would have become red hot and, if they were not steel covered, might have caused a fire. Or if steel covered they might have melted, breaking the circuit and causing great expense in finding the break and inserting new wiring. A fuse never allows a current much greater than that marked on it to flow through it without melting it. This protects the circuit and the building.

261. Grounding the Circuit. — We do not ground the electric current in our house lighting circuit, but it sometimes is accidentally grounded and may cause a "blow-out" or cut off our light in some part of the house by giving the current an easy way of getting back to the power house through

[1] "Short circuiting": allowing an electric current to take a short cut, thus reducing the resistance and increasing the current.

Popular Science Monthly.

Thomas Edison (1847–)

Edison was born at Milan, Ohio, February 11, 1847. As a young newsboy on trains of the Grand Trunk railway, in spare time he experimented with chemicals and ran a printing press in one end of the baggage car. At sixteen years of age he was a telegraph operator, but so busy was he thinking out improvements on his telegraphic instruments that he let messages pass unanswered, for which neglect he was discharged.

He soon invented the microphone and carbon transmitter which had much to do with the development of the telephone. Then came the quadruplex telegraph, the perfection of the Remington typewriter, and the phonograph.

Perhaps his greatest contribution to the present age is the electric light. To perfect it cost him untold labor and a world-wide search for a proper material for filaments. He next perfected the electric motors on street cars.

All these great additions to our present comforts we owe to the endless labor of this man, who sleeps but four hours out of every twenty-four and calls his work pleasure. Edison has turned out as many as 100 inventions in one year. Two of them are very popular to-day: the moving picture machine and the storage battery.

Edison says: "Genius is 1% inspiration and 99% perspiration." No other man in the world's history has ever developed so many examples of applied science.

the ground. A demonstration with the apparatus will show how this is done.

Demonstration 31: *Problem: How is an electric circuit grounded and why is it important that you know the dangers of grounding?*

Materials: The same as in Demonstration 29. (Key Picture 10.)

Method: Open all the switches. Put in new fuse wire. Insert the nail plug. Connect one bare end of the insulated wire to a water pipe, water faucet, or the steam radiator. Fasten the other end to one of the nails. Now close the switches. If nothing happens, fasten the wire to the other nail. What is the wire to the pipe doing for the current?

Disconnect the wire from the nail. Put in a new piece of fuse wire. Touch the bottom of an electric bulb to the nail which produced results before and touch the wire from the pipe to the brass side of the bulb. Note what happens.

Remove the wire from the side of the bulb. Between the two switches place a piece of wire with its insulation removed. Stand on a dry spot or put on rubbers. Close the switches. Touch the bare wire with one hand. *Keep the other hand free.* What happens?

NOTE. — If, at the same time, you touched a water pipe with your other hand, your body would conduct and ground the circuit. Why do you stand on a dry spot?

Observations: Write fully in your Science Discovery Book what happened.

Conclusion: Write out your conclusion. What must one always avoid in holding live wires?

Practical Application: Why is not a bird electrocuted[1] when it perches on a live wire? If a man is obliged to pick up a live wire, where should he stand? Why is it best always to leave live wires which have fallen into the street alone? How could grounded circuits occur in your home?

262. The Electric Arc. — An arc light in the street is of great use, but an arc[2] on a house circuit is a dangerous thing. One should never set up the conditions for the formation of an arc. Wires loosely connected in a socket can form an arc. If the ends of the wires are not twisted around and out of the way, they may come close enough together to form

[1] Electrocuted: killed by an electric current.

[2] A bow of flame, formed when a strong current jumps across the space between two adjacent electrodes (current carriers).

an arc. *Two bare wires should never be twisted about each other and then taped.* Each wire should be taped separately if the wires must go side by side. The danger from contact of broken or loose wires is great. For this reason there is always danger in an extension light because the constant moving of the light may wear off the insulation and cause an arc, or the connections may become loose.

In connecting electric utensils, it is always wise to turn on the socket switch first. Then push in the plug of the attachment. In disconnecting, always leave the socket switch alone until the plug is fully disconnected. This precaution is necessary because it often happens that the snap switch of the socket becomes worn, does not have enough spring in it to form a good wide gap and an arc is set up in the socket. A sizzling noise in the socket is a sure sign of an arc. Unscrew the socket plug at once and turn off the current at the fuse plug in the cellar. Have an electrician examine and adjust the socket or put in a new one.

263. Parallel Circuits. — You know from experience that the removing of one bulb has no effect upon the other bulbs

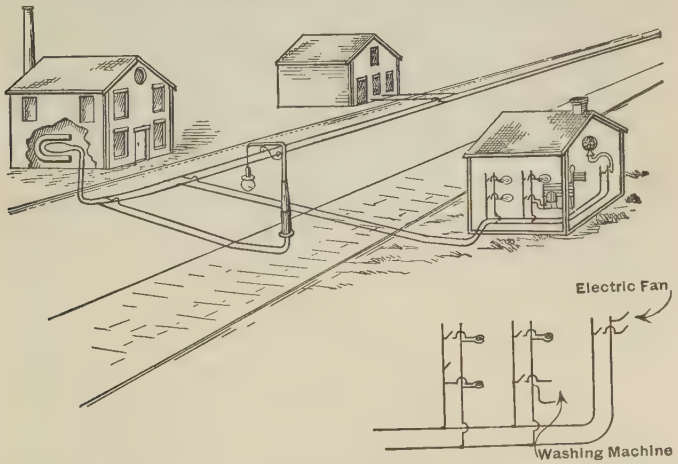


FIGURE 156. — HOW HOUSES ARE CONNECTED AND WIRED IN PARALLEL.

If the street lamp goes out, will it effect the lights in the two houses? Why? The washing machine and electric fan are independent of each other. How can this be? Explain fully.

in the circuit. Why is this? Simply because all houses are wired in *parallel*. There are always two parallel lines or wires across which all lights are connected. As the current comes along the circuit from the wall outlet, it will meet the first bulb socket. If the switch is off or no bulb is in the socket, the current passes on to the next light.

Study Figure 156 and answer all questions upon it.

What is true of the circuit in one house is also true of the larger street circuit. All houses have their circuits connected with the street lines, which are also in parallel. Thus if one house shuts off its current for the summer, it has no effect upon the current to the other houses on the same block.

264. How Electricity Is Sold. — Inspection of an electric light bulb will often show a label stamped on the end of the bulb indicating the number of *watts* or units of power the light will use. A watt is a unit of power so named in honor of James Watt, an English inventor who lived from 1736 to 1819. Since a watt is a very small unit of measure, 746 watts equaling one horse power, 1000 watts or 1 kilowatt is used as the unit of measure and we buy our electricity in kilowatt hours. If 1 kilowatt hour costs 10 cents, then one can use 1000 watts one hour for 10 cents. To find out how many watts you are using each hour, say in an electric iron, you simply multiply the number of amperes which the iron carries (say 5), indicated on the iron, by the voltage, which is generally 110, and you get the watts, — 550. If 550 is divided by 1000 watts, the number of watts in a kilowatt, we get .55 of a kilowatt. At 10 cents per kilowatt, the iron will cost .55 of 10 cents or $5\frac{1}{2}$ cents an hour to use.

265. Electric Current and the Work of the World. — Heat, light, and power may be frequently produced by electrical energy. We know practically nothing of the nature of this wonder worker, but we use it as freely as water. It is clean, quiet, easily handled, powerful, and efficient. Moreover, it is cheap. It is the greatest helper we have in this age of industry, comfort, and labor-saving devices. It makes crime less attractive. How? It makes possible the automobile, the trolley car, the electric motor. It is a mysterious power which men will continue to study and use. No factor

General Electric Company.

FIGURE 157. — TWO GREAT MASTERS OF ELECTRICITY. THOMAS EDISON AND CHARLES P. STEINMETZ.

The world is a better place in which to live because of the untiring work of these investigators.

of our environment is more interesting to study or is more useful in making our lives more comfortable than this peculiar form of energy. It has been without doubt the greatest factor in the tremendous industrial progress of the last twenty-five years, a period now known as the Age of Electricity.

REVIEW OUTLINE

1. The Compass: (1) Use; (2) comparison to a magnet; (3) relation to the earth.
2. Magnets: How produced; poles. How magnetism is produced in objects. How a magnet works. Lines of force.
3. Frictional Electricity: How produced. Kinds. Conductors and non-conductors.
4. The Nature of Electricity: Molecules; atoms; protons; electrons, stationary and free. The frictional flash.
5. Current Electricity: Comparison with the frictional form; how generated; positive and negative poles. Storage batteries: structure; uses in automobiles, radio, etc.
6. Uses and Control of Electric Currents: Importance of constant current. How made and broken. Switches. Lamps. Resistance. Fuses; structure and importance. Short circuits; how produced, how prevented; dangers. Grounding of Circuit: Nature; cause; dangers; how prevented. Electric arc: Nature; cause; dangers; how prevented. Parallel circuits: Nature; importance in the home.
7. How Electricity Is Sold: Watt; kilowatt. Meaning. James Watt. How amount of current used is computed.
8. Electricity and the Work of the World. Greatest factor in: (1) industry; (2) home; (3) transportation.

SUMMARY

The invention of the *compass* was a great stride in the history of civilization. Because of its tendency to point towards the magnetic north pole of the earth, it is a safe guide in travel on the seas.

The use of the compass developed the *magnet*. A study of the magnet disclosed the *lines of magnetic force about its poles*. The work of eminent scientists showed that a wire when revolved between the poles of a magnet produces an electric *current*. Further study showed that an electric current is a movement of extremely small particles of energy called *electrons*. Electric current may be produced by *dynamos* and stored as *chemical energy*. The storage battery is of great use in producing strong currents for short periods of time, as in the ignition of an automobile, for testing, and in the radio. The dynamo produces an even current of great strength and so is used to supply power, light, and heat.

Current electricity is controlled by *switches*, by the *size of the wires* used, and by *fuses*. Too high amperage on a line blows the fuse. The blowing of the fuse prevents fires. Dangers in electric

circuits arise from *short circuits*, *grounding*, and *electric arcs*. All can be prevented by care and by use of special conduits, insulation, and skill in making connections.

Electric current is sold by the watt, the kilowatt-hour being the ordinary unit. The amount of electrical current used in one hour may be computed by multiplying the amperes by the volts used. Electricity is the wonder worker of the age.

Remember that:

1. An electric current is a form of energy.
2. Current electricity is a movement of electrons along a conductor.
3. Electricity will always follow the line of least resistance, and it can be stored as chemical energy for future use in batteries.
4. Electric currents can be controlled by the use of fuses and switches, thus preventing fires.
5. Electrical currents can be generated by dynamos and carried long distances on wires. They can be measured and used to light buildings, propel cars, supply heat, and run factories.

THOUGHT QUESTIONS

1. How may you magnetize a knife blade?
2. Why is it best to put lightning rods on tall chimneys?
3. Where is it best to stand during a thunder storm? Why? Where is it bad to stand? Why?
4. What insulation is best for the wires about your home?
5. Why are lightning rods carried deep into the ground?
6. Why can a motorman stand on top of a trolley car and hold the trolley pole without receiving a shock?
7. Why are automobiles seldom, if ever, struck by lightning?
8. Why is it bad to put a 30-ampere fuse on a 15-ampere wire?
9. How can you identify the poles of an unmarked bar magnet?
10. Will the compass work best on wooden, iron, or steel ships?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Darrow. The Boy's Own Book of Great Inventions. The Macmillan Co.

Gibson. Electricity To-Day. J. B. Lippincott Co.

Seaver. The American Boy's Book of Electricity. McKay Co.

Willoughby. Practical Electricity for Beginners. Manual Arts Press. Peoria, Ill.

NUMBER KEY TO PLATE III

Agriculture: 1, primitive hoe; 2, sickle; 3, an early reaper; 4, an early cradle and thresher; 5, power harvester.

Building: 1, cave-dwelling; 2, Indian lodge; 3, teepee; 4, thatched hut; 5, log cabin; 6, a modern house; 7, a modern business block.

Land Travel: 1, foot; 2, pole drag; 3, coach and four; 4, early steam railway; 5, trolley car; 6, limousine; 7, steam locomotive; 8, electric engine.

Water Travel: 1, canoe; 2, raft; 3, schooner; 4, steam and sail; 5, modern steamer and motor boat.

Air Travel: 1, kite; 2, balloon; 3, early dirigible; 4, modern dirigible; 5, airplane.

Communication: 1, fire; 2, stone tablet; 3, cannon; 4, pony messenger; 5, telegraph; 6, newspaper; 7, telephone; 8, radio.

Water Power and Electricity: 1, water-mill; 2, modern power house and dam.

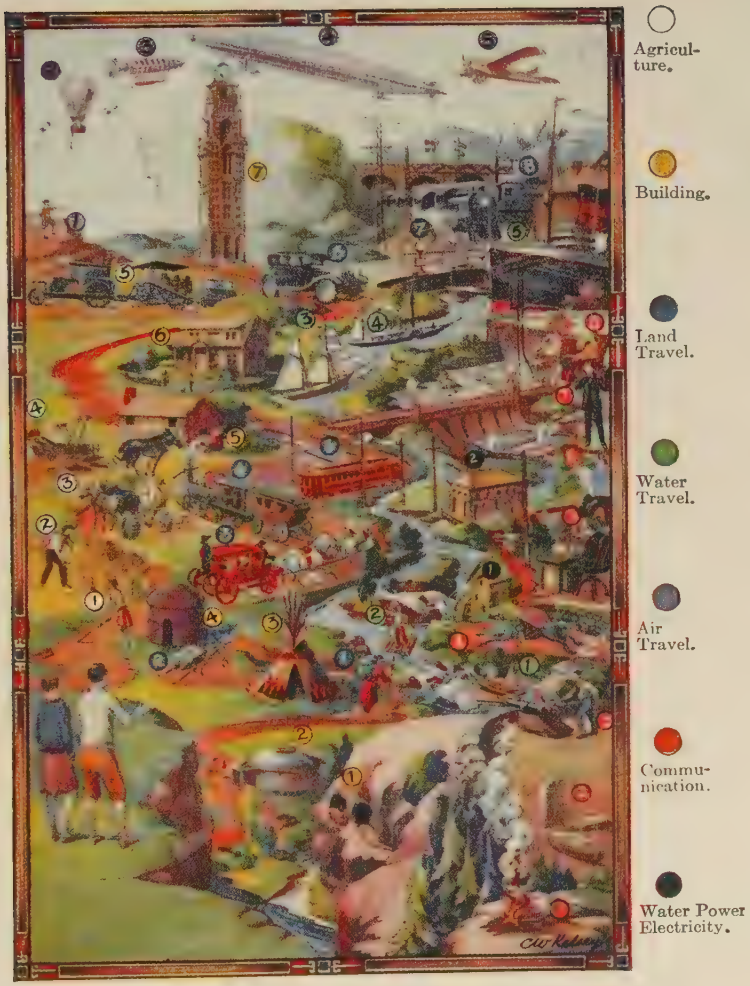


PLATE III.—THE DEVELOPMENT OF INDUSTRY.

Follow each path with your eyes just as the boy and girl are doing. Using the color key at the side, trace all seven of the series shown. The number key on the opposite page will help you do this. Then write the complete story in your Science Discovery Book.

PART III

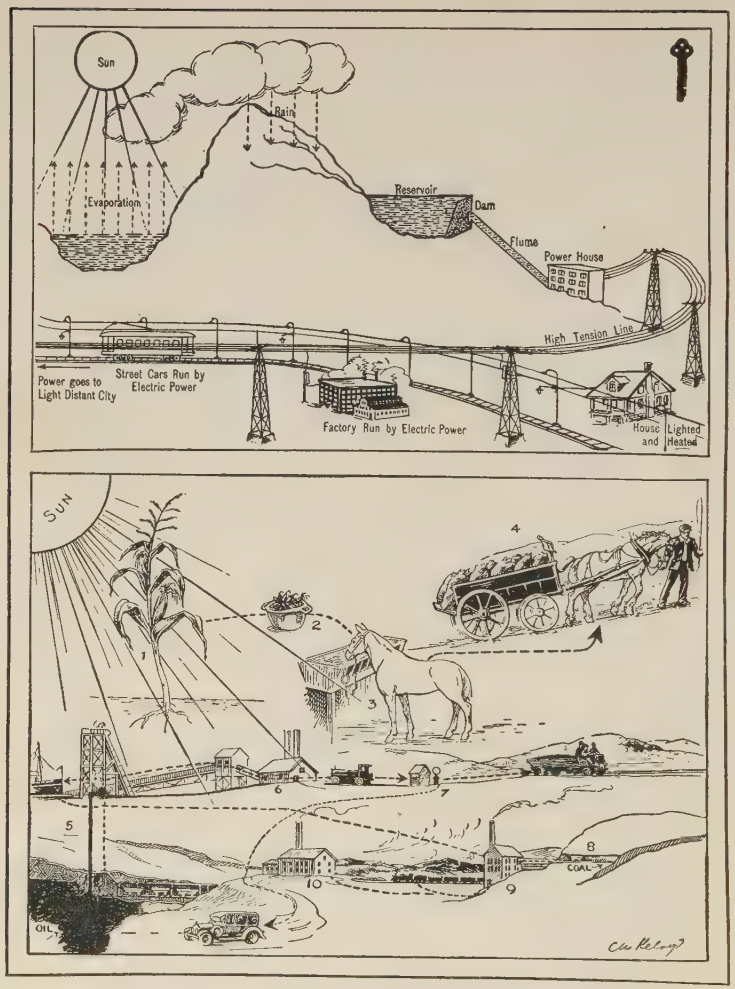
THE IMPORTANCE OF INDUSTRY

Scientific truths are often stranger than fiction.
— Wood.

Air, water, heat, electricity, and light are very common yet very important factors of your environment. The greatest thing you have discovered about these factors in the last few chapters is the fact that they can all do work. It took man a long time to discover this fact for it is a long, slow process to find out new ways of using these factors in lightening work.

Some people are always at work and we call them *industrious.* Industry is a special kind of work in which some useful product is the result. Industry developed as men found out some of the uses to which their environment could be put. Raw materials were made into utensils, tools, machinery, vehicles, and buildings. To do this required energy, and men soon learned to use air, water, heat, electricity, and light on a vast scale to produce enormous numbers of useful things. Varied industries make possible greater populations, which mean a greater demand for and use of manufactured products. Industry feeds the people of the world and uses the natural resources of a country to increase the comfort and happiness of the people.

You can gain from a study of a few selected industries a general knowledge of some industry in your own town and of the important principles used in the conduct of the leading industries of agriculture, manufacturing, building, transportation, and communication.



KEY PICTURE 11.—TRANSFORMATION AND USES OF ENERGY.

Study each picture until you see the relations of all the parts. What is the relation between 1, 2, 3, and 4 in the lower picture? What caused 1 to grow? What really pulls the load up the hill?

Oil and coal are products of organisms which lived millions of years ago. What, then, really makes the train, the truck, the sedan, and the steamship move? What really runs the factory? Now tell the whole story of each picture.

CHAPTER XI

THE WORK OF AIR, WATER, HEAT, AND ELECTRICITY IN INDUSTRY

Joy to the Toiler! — him that tills
The fields with plenty crowned;
Him with the woodman's axe that thrills
The wilderness profound;
Him that all day doth sweating bend
In the fierce furnace heat;
And her whose cunning fingers tend
On loom and spindle fleet!
A prayer more than the prayer of saint,
A faith no fate can foil,
Lives in the heart that shall not faint
In time-long task of toil.

— Benjamin Hathaway, "Songs of the Toiler."

What Do You Know about a Factory?

Did you ever go into one? Would you like to enter one and find out how work is done in it and where the power comes from that runs it? Did you ever stop to think where all the machinery comes from? Do you suppose that heat ever had anything to do with the making of this machinery? Do you know just how a steam engine works? How can it run the factory? Do you know how water power can be made to take the place of a steam engine? Do you want to find out? Have you ever thought just what makes an electric fan work? Many shops are run by electric current. Where does it come from? How does it turn the wheels of the factory? Well, you can find out all these things in this chapter.

Some Practical Questions:

1. What is the most common form of energy used in manufacturing to-day?

2. How can you prove that most factories are run by preserved sunshine?

3. Why must heat energy always be changed to motion in a factory?

4. One hundred years ago, all mills were on streams. Give reasons why few mills are now on streams.

5. With what industry is your family most closely connected?

6. Is this industry the production of a raw material or the manufacture of a finished product? Explain.

7. Suppose that all men should at once decide to become farmers. Explain fully all the results that would follow this action.

Home Problem. — Secure, if possible, a small soldering set and mend some leaks in your mother's tinware with it. As you work, explain the action of the heat on the solder and what happens to the solder to make it of value in mending. Explain the use of the acid. Report to the class.

Field Problem. — If possible, study and observe the transformation of energy in a steam derrick or shovel. Find out just how the machine works and determine how many men's labor it saves.

1. Why Do Men Work?

266. What Is Industry? — The control and use of the factors of our environment in the production of useful materials is called industry. Examples are mining, manufacturing, building, transportation, agriculture, the preparing and using of food in the home, and the communicating of messages by mail, telephone, telegraph, cable, and wireless.

267. How Industry Began. — In the earliest times men were nomads,[1] wandering over the surface of the earth in quest of food and shelter. They lived in caves, sheltered cañons,[2] or deep forests, and fed upon roots, wild fruits, and such animals as they could kill by use of stick or stone. As time and experience developed their reasoning powers, they learned in their hunting to capture alive and save some

[1] Nomads: wanderers.

[2] Cañons: deep valleys with high, steep walls.

animals, thus producing a steady supply of food without much exertion in hunting. *Thus herding began as an industry.* The skins of the animals were used as clothing and their meat fed the tribe. Soon man discovered the gainful side of work and the advantage of exchanging one commodity[1] for another. Commerce then began.

2. How Modern Industry Developed

268. Minerals and Machinery. — One of the great industries is mining. Ores are dug out of the earth, refined, and

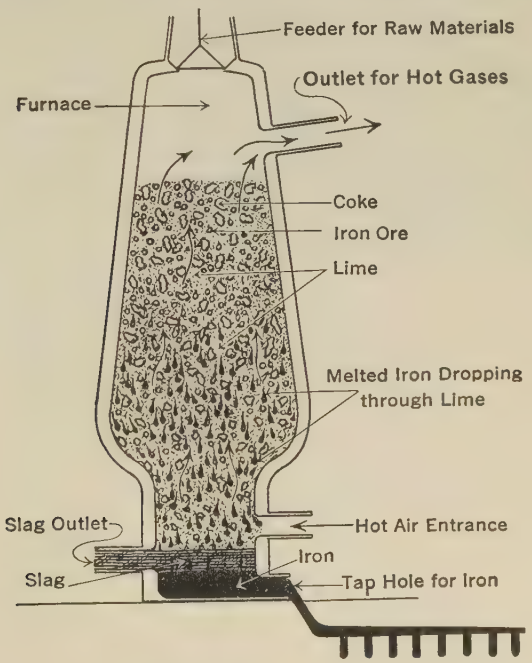


Figure 158A. — The Blast Furnace (Interior).

What do the coke and lime do to the iron ore? What is slag? Why is hot air sent into the furnace? What gases come out of the furnace? Which is heavier, iron or slag?

[1] Commodity: a useful thing which can be bought or sold.

SOURCES, TREATMENT, AND PRODUCTS OF IRON ORE

Raw Materials Used in Reduction

Iron Ore
Limestone
Coke or Carbon

Fuel → Blast Furnace ← Heated Air

Products

Blast Furnace → Slag

Blast Furnace → Ballast, Cement, Fertilizer

Blast Furnace → Pig Iron

Pig Iron	
iron	93
carbon	4
other matter	3
	100%

Processes for Refining

Pig Iron →
- Open Hearth ①
- Bessemer ②
- Electric Furnace ③
- Foundry ④
- Puddle Mills ⑤

Blast Furnace → Dust, Gases

Finished Products

① Structural steel for buildings, bridges, rails, axles, sheet metal

② Nails, rods, bars, tubes, pipes, armor plate, castings, malleable steel

③ Cutlery, tools, instruments, firearms

④ Stoves, machines, ornamental iron work, implements

⑤ Wrought iron, electromagnets, hinges, nails, forge work

All the above are used in garden, on farm, in house, in manufacturing, transportation, communication, construction, arts, and sciences.

Iron Ore Sources

Lake Superior	81%
North Eastern	5%
Southern	12%
Western	2%
	100%

Reduction Centers

Pittsburgh, Pennsylvania
Chicago, Illinois
Birmingham, Alabama
Cleveland, Ohio
Gary, Indiana
Buffalo, New York

made into machinery. Machinery is linked up with power and put to work. From the ore to the machine is an interesting story. Let us see how ore is refined.

Demonstration 32 : *Problem: How is pure metal produced from ore?*

Materials: A piece of lead ore; a small quantity of lead oxide (pulverized lead ore containing oxygen); a blow pipe; a Bunsen burner; and a small block of willow charcoal with small hole $\frac{1}{4}$ inch deep hollowed out of its center.

Method: Place a small amount of the lead oxide in the hollow of the charcoal. Blow against this oxide the flame of a Bunsen burner by use of the blow pipe. Blow steadily for some moments watching the effect upon the oxide.

FIGURE 158B. — A MODERN BLAST FURNACE OF THE CARNEGIE STEEL COMPANY (EXTERIOR).

Note the piles of ore on the charging side of the furnaces. Compare with Figure 158a and explain the principle of the furnaces as shown here.

Observations: What change in color do you note? Does the oxide glow? What begins to appear on the surface of the oxide? What does it resemble? This is pure lead. What element is found in every oxide? What elements are found in pure lead oxide? What does the process remove from the lead oxide? With what element in the charcoal and what element in the gas of the flame might this element which is removed from the oxide unite? Explain.

Conclusion: What really happens when ores are refined or reduced? What do you suppose is used in the great smelting mills to remove oxygen from ores? Name several metals produced from ores.

269. How Ores Are Reduced. — Iron ore is iron oxide (a compound of iron with oxygen) mixed with carbon, sulphur, and small amounts of other elements. To get the pure metal, we must remove the oxygen and also any impurities from the compound. This is done by means of what is known as

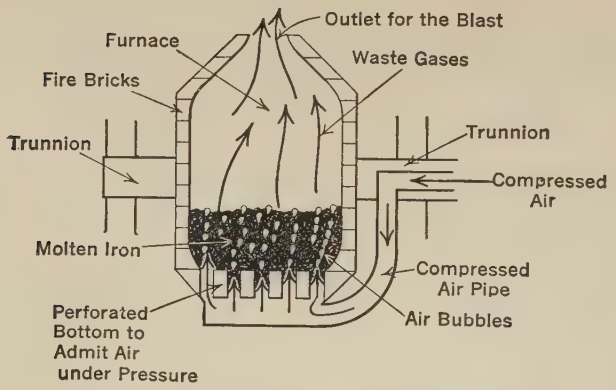


FIGURE 159. — THE BESSEMER CONVERTER (INTERIOR).

Why is this apparatus placed upon trunnions so that it can be inverted? Explain the function of each labeled part.

a blast furnace, 100 ft. high and 25 ft. or more in diameter. The result is *pig iron*. Study Figures 158a and 158b and answer all the questions upon them. Can you tell how the sun really helps in refining ores?

Brown Bros.

FIGURE 160. — THE BESSEMER CONVERTER IN ACTION (EXTERIOR).

Compare this with Figure 159. What causes the flame which shoots from the mouth of the converter?

270. Production of Steel. — Five-sixths of all pig iron is made into steel. How is this accomplished? Several methods are used, producing various textures in the metal, but the Bessemer process is fundamental to them all. Study Figures 159 and 160 until you understand them.

Steel is thus a refined

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Henry Bessemer (1813–1898)

The use of iron was known 4,000 years B. C., but it was not until 1856 that the process of making steel quickly in large quantities was discovered by Sir Henry Bessemer, in an effort to improve the quality of cannon. The railroad, steel ships, skyscrapers, big guns, and the machinery of agriculture so common and important to-day would be impossible without the Bessemer process. Electrical power transmission depends upon steel. Steel is the basis of the prosperity of the world to-day.

Bessemer early showed a genius for invention. He was not afraid of work and during his eighty-five years he continually put upon the market new devices to aid the labor of man.

About 1865 Bessemer set to work to discover a new process of making cheap steel. He tried the experiment of oxidizing the impurities from molten iron by an air blast. The result was a steel of very fair quality. He next invented the Bessemer converter (Fig. 159) and after many failures produced in his Sheffield works a grade of steel which soon became world famous.

Bessemer lived to be honored with knighthood and was held in high esteem by the people of the whole earth. He added much to the prosperity and wealth of the world.

form of iron. The various kinds of steel are the result of mixing the molten metal with certain elements (silicon, carbon, tungsten, etc.) which supply the desired characteristics.

271. How Steel Is Made Tough. — Steel is made strong and tough by being tempered. In a blacksmith shop it is plunged into water when hot. By plunging steel heated to a certain temperature into water the best tool steel is made, to be used in the manufacture of razors, chisels, watch springs, surgical instruments, and the like. Would modern industry be possible without steel?

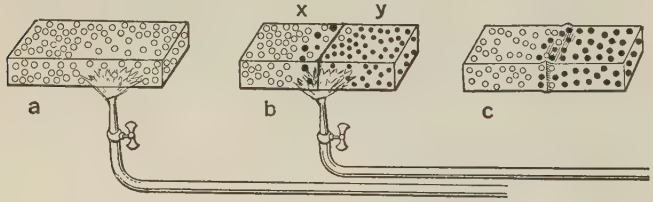


FIGURE 161. — HOW WELDING IS DONE.

Note the molecules beginning to separate in **a**. Explain. Two pieces of steel of different kinds (**x** and **y**) are being welded at **b**. What is happening to the molecules in both **x** and **y**? At **c**, **x** and **y** are joined together (welded). What locked them together? Account for the ridge in **c**.

272. What Happens to Iron When It Fuses. — How can iron or steel be made into a liquid so that it can be dipped up in a spoon as one would dip up water or milk? You have already discovered that when heat acts upon the molecules of a substance, the spaces between the molecules enlarge, the molecules themselves become very active, and begin to slip by one another. When all of the molecules become agitated in this way, the whole mass begins to flow like water (Fig. 161).

273. Welding. — This wonderful property of molecular activity makes it possible to cause the molecules to fit into any form desired. Thus we have castings and molded iron. It also makes it possible to rivet steel girders together by the use of red hot bolts which, when put in place, can be ham-

mered tight. When cooling they shrink and make the riveting still tighter.

But even more wonderful than this is the power of these metals to fuse in the process of welding.

274. Cutting Steel Plates. — Iron and steel cannot long endure extremely high temperatures without fusing. For this reason, an oxy-acetylene flame will cut holes through steel plates in a very few seconds (Fig. 162). Thus rivet holes can be cut in heavy metals such as thick steel plates, armor plate, flume plates, and castings. Such metals can be fused along a given line and quickly cut into sections. In this way old warships are wrecked and made into junk. During the World War ships were cut in two, passed through the locks of the Welland Canal in halves, and welded together again at the end of the trip.

FIGURE 162. — CUTTING STEEL PLATES WITH AN OXY-ACETYLENE FLAME.

How does the flame affect the steel? Why does the operator wear goggles?

275. The Importance of Power. — Energy in the form of heat can do an enormous amount of work in causing activity in the molecules of iron, steel, and other metals. It is interesting to know, however, that this is just the beginning of the use of heat in industry. In fact the very ore which is taken from the ground is made by heat into machinery and tools which will mine and refine more ore. Steel tools are used to make more tools; machinery is used to make more machinery.

Since most of our work in industrial plants is done to-day by the burning of fuel, it follows that the power plant is the core of our complex system of industry.

FIGURE 163. — THE RESULT OF THE WORK BEING DONE IN FIGURE 162. These steel plates, over six inches thick where riveted together, were cut by the oxy-acetylene flame.

3. How the Steam Engine Began the Age of Industry

276. The Importance of the Steam Engine. — It is believed that all the steam engines of the world are now doing about 200,000,000 horse power of work each day, which is more than could be done by every adult human being in the world working hard for the same length of time. Modern industrialism had its beginning in the invention of the steam engine. Make a list of all the industries of your town which use steam to run their machinery.

Demonstration 33 (Teacher's Demonstration): *Problem: How is steam produced and what are some of its properties?*

Materials: A tin coffee pot; a Bunsen burner; an iron ring stand or iron tripod; putty; and water.

Method: Fill the coffee pot about one-third full of water. Place on tripod and apply heat to the bottom. Watch for results. Next from the inside seal the holes of the spout of the pot with putty. Apply heat again. Watch for results.

Observations: What first appeared at the spout? What did it look like? Of what was it composed? What happened when the spout was sealed? Does steam possess energy? Do you think it can do work? Explain.

Conclusion: How can steam be generated? What are some of its powers or properties?

277. How Steam Power Originates. — When sufficient heat is applied to water, the molecules become very active and widely separated, and many of them are changed into steam bubbles. During this process expansion takes place at a terrific rate, and the steam occupies, if unrestrained, a space 1600 times greater than the volume of water from which it was made. Thus, a cubic inch of water will produce about a cubic foot of steam. Steam then has the power of *expansion*.[1]

A second characteristic of steam is its *compressibility*.[2] When it is confined in a tight inclosure it will, in attempting to get out, exert enormous pressure against the sides of the container. If this container is strong enough, and the steam is allowed to escape through a small opening, it can be made to produce a noise, as in a whistle, or to do work. It is the expansion and the compressibility of steam that make it of such great value in the world's work.

An Englishman named Newcomen made the first successful stationary engine used in manufacturing. It was really an air-steam engine. Carefully study Figure 164 and be able to explain just how this engine worked.

---

[1] Expansion: an increase in size, generally under the influence of heat.

[2] Compressibility: the property of being compacted or pressed together.

278. The Work of James Watt. — A study of the biography of this man (see opposite page) will give you many interesting facts about him. But the big thing he did was to improve the Newcomen engine. So important were the changes which he made in 1774 that his engine is practically

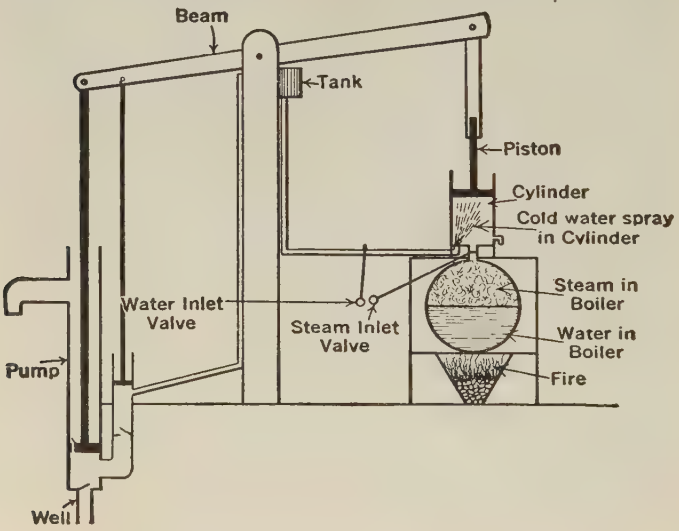


FIGURE 164. — THE NEWCOMEN ENGINE.

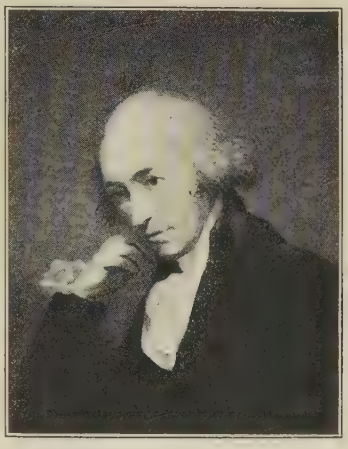
Note the cold water spray. This caused a vacuum. What pushed the piston down? What pushed it up? The inlet valve was worked by hand. Why was this a poor arrangement?

the same engine that is used to-day in our factories and on our railroads. Study Figure 165 until you can explain just how the first Watt engine worked.

279. How an Engine Works. — Your previous demonstration with the generation of steam showed that steam possesses power. It lifted the coffee pot cover. The inventive genius of men found a way by which this expansive power could be made to give a push on a surface which in turn could cause a rotary motion in a wheel. This is the principle of the modern steam engine.

James Watt (1736–1819)

James Watt was born at Greenock, Scotland, in 1736. As a boy he constantly thought of the possibility of making steam do work in moving machinery. He had a great liking for mechanics and, when a young man, became an instrument maker. While engaged at this work, he was asked to repair a model of Newcomen's steam engine. He saw that this engine wasted four-fifths of its steam. He at once resolved to build an engine which would eliminate this waste. He pondered over this problem for two years, when suddenly while taking a walk one Sunday the complete solution of the problem flashed into his mind.



In 1760 the government granted Watt a patent on his model. Later this form was perfected by doing away with the use of atmospheric pressure in moving the piston down, and in place of this device steam was admitted alternately on both sides of the piston (Fig. 165). Finally a governor and a flywheel were added.

The greatest result of Watt's work was the beginning of the new era in the industrial life of the world. He ushered in the Age of Industry. He was the father of the Age of Power. The world can never pay its debt to this one man.

280. Modern Steam Engines. — The modern steam engine is a wonderful and comparatively simple mechanism. A careful study of Figure 166, together with the securing of

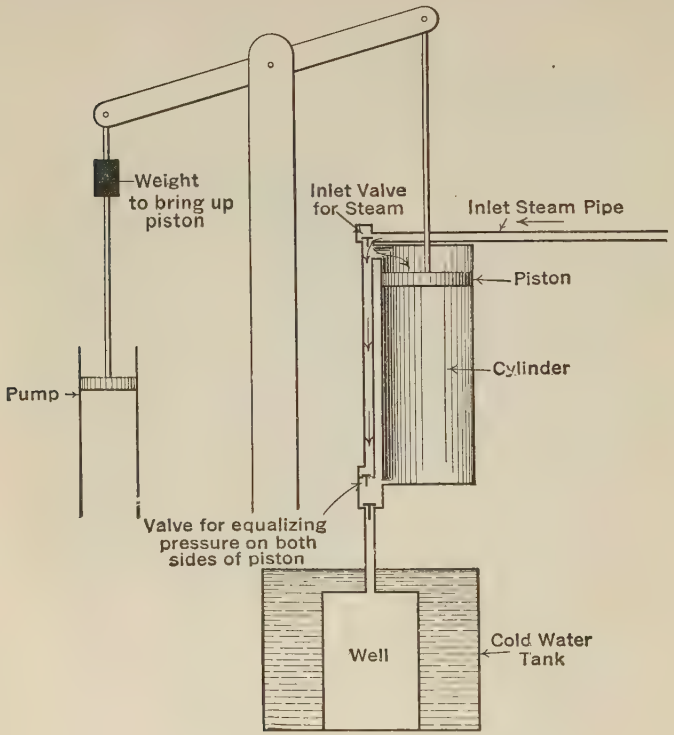


FIGURE 165. — JAMES WATT'S ENGINE.

Compare with Figure 164. The inlet steam valve and the well valve opened at the same time when the piston reached the position shown here. As the piston went down, the exhaust steam went into the well (condenser). The equalizing valve opened the moment the piston reached the bottom of the cylinder. The well and steam valves closed.

answers to the following questions upon it, will go far towards giving you a thorough understanding of it.

1. What causes the piston to move? 2. Where is the cylinder? 3. What is the use of valves in this engine? 4. Where is the steam

generated? 5. How does the steam reach the cylinder? 6. How does the steam get into the cylinder? 7. Do the valves work in any given order? 8. How is the speed of the engine governed?

The steam passes into a steam chest in the modern engine through throttle valves, sometimes operated by a governor. From here it

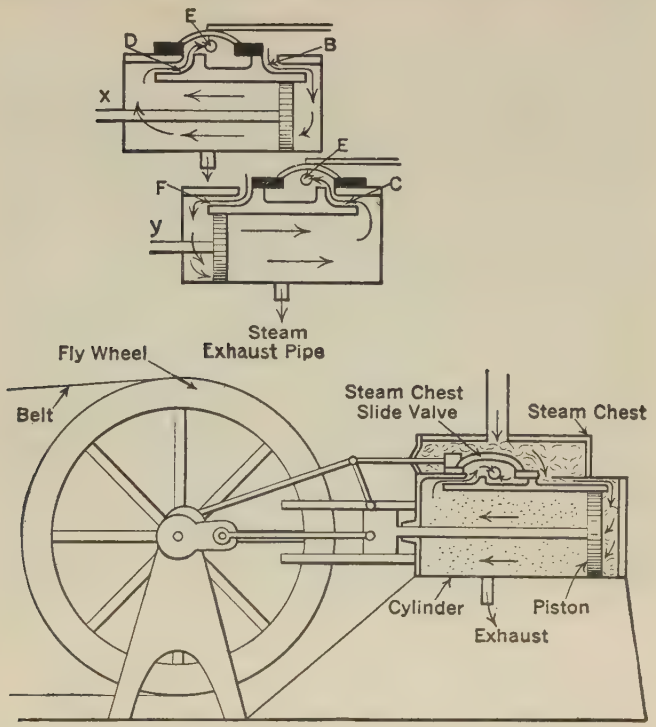


FIGURE 166. — A STATIONARY STEAM ENGINE.

Determine the function of every part as you answer the questions upon it in Section 280.

passes under high pressure through the port *B*, which is the only avenue for its escape, into one end of the cylinder. Instant expansion forces the piston to the other end of the cylinder, at the same time driving out the steam used in the previous stroke, through the exhaust port at *D*, and out through the exhaust pipe at *E*. Meanwhile the slide valve rod, fastened to the crank-shaft on an

eccentric (which is an off-center attachment), is pushed to the other end of the steam chest, changing inlet port *B* to exhaust port *C* and changing exhaust port *D* to inlet port *F*. The steam now rushes in on the other side of the piston, forcing the head back to the opposite end of the cylinder and driving out the spent steam to the outside air.

The speed of the engine is often controlled by a governor,[1] revolved by a belt attached to the flywheel. If the flywheel increases its

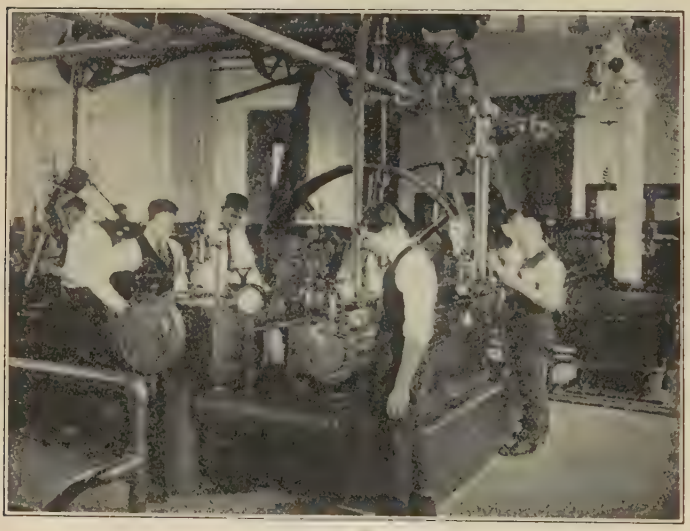


FIGURE 167. — HOW POWER IS DISTRIBUTED BY MEANS OF SHAFTS, DRUMS, AND BELTS. EXPLAIN.

speed, two heavy iron balls on the governor are forced apart by centrifugal force.[2] This partly closes the throttle valves, reducing the supply of steam entering the steam chest, and thus controlling the speed of the engine.

The boiler is an important part of a steam engine plant, since in it is generated the steam to run the engine. Explain.

Observe a steam boiler and note the steam pressure gauge and the safety valve.

---

[1] Governor: a device which controls the speed of steam engines, gas engines, or other motors.

[2] Centrifugal force: a force which tends to throw a rotating object away from the center about which it moves.

281. How the Steam Engine Does the Work of the World. — By means of an eccentric and connecting rod[1] the to-and-fro motion of the piston is changed into rotary motion in the flywheel.

Now the flywheel is provided with a large belt which is connected with a drum (a broad box-like wheel) on a main shaft. This main shaft may be fitted with several pulleys of different sizes, each one connected by belts to a machine flywheel, causing it to revolve and transmit energy to the machine (Fig. 167). To stop or start any machine, the belt is thrown from a loose to a fixed pulley, both attached to the same revolving shaft. The relative speeds of the different machines are determined by the sizes of the drums. Friction clutches and devices by which the belts are shifted to pulleys of different sizes on the machine shaft, aid in increasing or decreasing the speed. This is the way most of the work is done in the modern factory.

4. The Gas Engine — a Modern Worker

282. The Gas Engine. — In the gas engine we find a distinct advance over the stationary steam engine; we have what is called an *internal combustion* engine. The fuel is actually burned inside the cylinder of the engine, instead of in a boiler several feet away. Such fuel must be capable of being largely vaporized in the cylinder, since it must be in the form of a gas when oxidized. Such fuels are natural gas, water gas, coal gas, kerosene, petroleum, alcohol, finely powdered coal, and gasoline.

The first successful gas engine was built in France in 1861, while in this country no one ever saw a real gas engine do work until 1873. Yet so rapidly has it developed and so efficient has it become that a steam engine, to equal its efficiency, would require $2\frac{1}{2}$ times as much fuel to do the same amount of work.

[1] Connecting rod: a strong steel rod connecting the flywheel with the piston.

Demonstration 34 : *Problem: How does a gas engine work?*

Materials: The same coffee pot used in Demonstration 33 ; illuminating gas ; a Bunsen burner ; putty ; rubber tubing ; and wire.

Method: Cut a small round hole in the side of the pot near the bottom. Solder a gas burner to this hole. Attach the piece of rubber tubing to the gas outlet and the burner. Cut a small round hole in the side of the pot about halfway from the top to the bottom. Plug the spout on the inside with putty. Allow gas to escape into the pot for about three seconds. Close cover. Fix wire to handle as shown in Figure 24. Hold a lighted match to the small hole in the side. Watch the results. Repeat the operation. Now open cover and apply lighted match to the gas in the pot. What happens? Now close the cover and let in some more gas ; open cover enough to let in a little air. Then close it again and apply match as before. What happens now? Account for the difference.

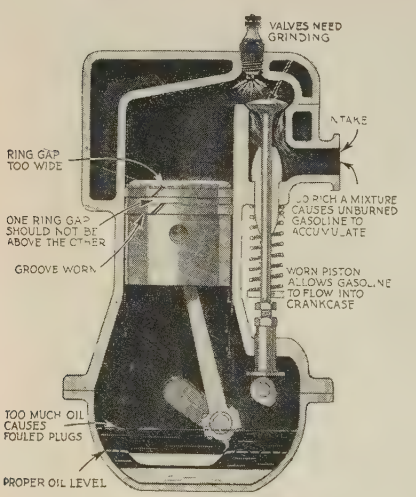

VALVES NEED GRINDING
INTAKE
RING GAP TOO WIDE
TOO RICH A MIXTURE CAUSES UNBURNED GASOLINE TO ACCUMULATE
ONE RING GAP SHOULD NOT BE ABOVE THE OTHER
GROOVE WORN
WORN PISTON ALLOWS GASOLINE TO FLOW INTO CRANKCASE
TOO MUCH OIL CAUSES FOULED PLUGS
PROPER OIL LEVEL

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FIGURE 168. — A ONE-CYLINDER GAS ENGINE.

Compare with Newcomen's engine. Try to find out the function of each part. Note how the cam pushes the valve up as it turns. Notice the conditions that are wrong in this picture. Explain.

Observations: What happens to the coffee pot cover? What is the use of the wire? What causes the cover to rise? Why does it rise suddenly? What causes the gas to ignite? To what part of a steam engine might you compare the pot itself? the cover? Why is the gas engine called an internal combustion engine?

Conclusion: State in your own words the principle of the gas engine. What makes the gas engine so efficient? Write out this demonstration in your Science Discovery Book.

283. How the Gas Engine Works. — The simplest type of gas engine consists of one cylinder and is surprisingly like

Newcomen's air-steam engine in that the end of the cylinder is open (Fig. 168). This allows free movement of the connecting rod between the piston head and the crank shaft. Carefully study Figure 168 and explain it to the class.

5. Our Future Power Supply — Water

284. Power and the Coal Supply. — About 75% of all power used in the United States is generated by burning coal and of the remaining 25%, 3% is furnished by natural gas,

Figure 169. — The Muscle Shoals Dam.

The greatest dam in the world. It impounds the waters of the Tennessee River for the purpose of turning turbines which will furnish power to run plants for making nitrates and other products.

oil, and wood, 2% by the wind, and 20% by falling water (see Plate III).

It is estimated that the available water power in the United States is about 100,000,000 horse power, or about one horse power for every person in the country. To use this

tremendous power, engineers must build great dams of stone, steel, and concrete. As it is made available, there must be wise control of the water power and the conservation of our forests by the Federal and State governments should be encouraged. (Key Picture 11.)

When you come to vote as a citizen, you should use your influence to secure proper control and preservation of our great water power sites for the use of the whole people.

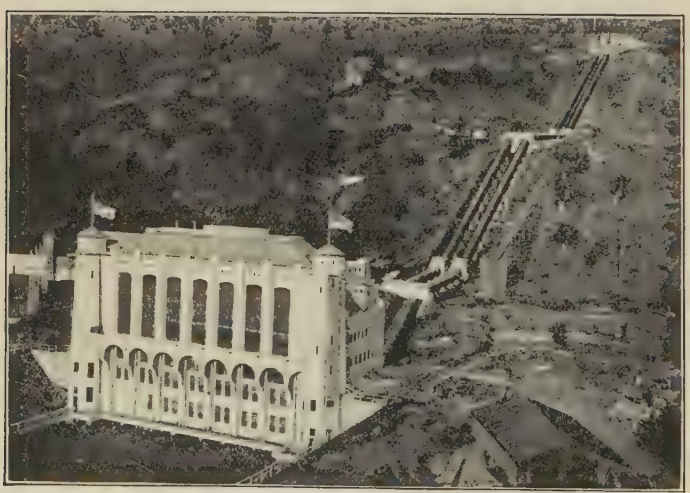

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FIGURE 170. — A WESTERN POWER HOUSE.

This plant furnishes power to the San Francisco region. Note the enormous flumes. Where is the dam? Where are the dynamos located? What causes them to turn?

285. How Water Power Is Made Available. — Modern concrete and steel construction makes it possible to erect enormous dams holding millions of tons of water (Fig. 169). From these dams enormous flumes, constructed of steel cylinders riveted together, carry the water under tremendous pressure to where it can drop upon steel water wheels, called *turbines,* which are set in a horizontal position in the

power plant. Gates and valves control the amount of water flowing through the flume. Thus, the speed of the turbines can be accurately controlled and roaring streams or sluggish rivers are made to respond to a lever in the hand of man (Fig. 170).

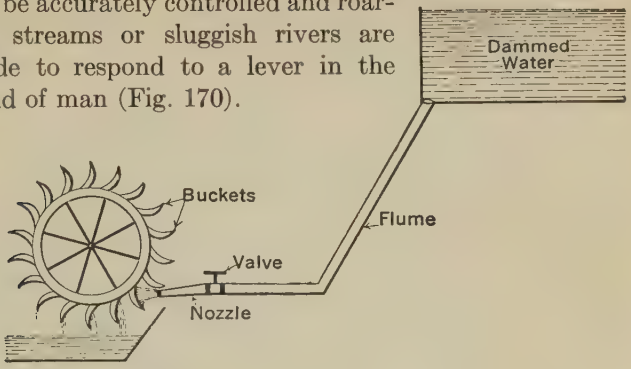


FIGURE 171A. — THE PELTON WHEEL.

An adjustable nozzle sends the water with tremendous force against the buckets of the wheel. What gives the water its great force?

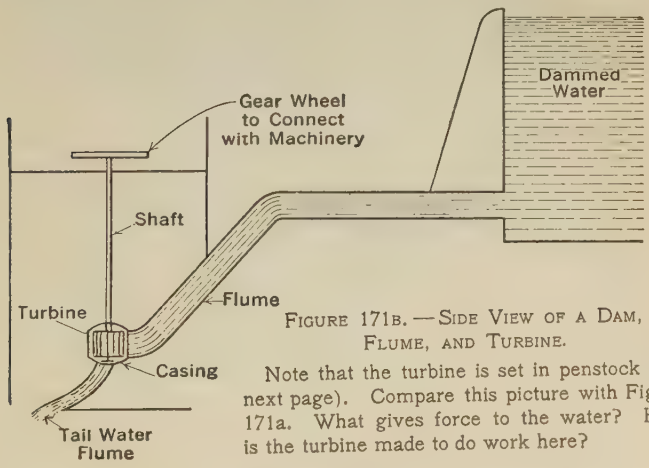


FIGURE 171B. — SIDE VIEW OF A DAM, FLUME, AND TURBINE.

Note that the turbine is set in penstock (see next page). Compare this picture with Figure 171a. What gives force to the water? How is the turbine made to do work here?

286. Types of Water Wheels. — At present two chief types of water wheels are in use, — the Pelton and the turbine. The first, named from the carpenter who invented it, can generate from a part of a horse power to twenty thousand

horse power. It is especially adapted to small streams with high head and is, therefore, more commonly used in mountainous regions (Fig. 171a).

287. The Turbine. — The turbine is used where the volume of water is large and its fall not great. Study (Figs. 171b and 172) and tell how the turbine is built and how it works.

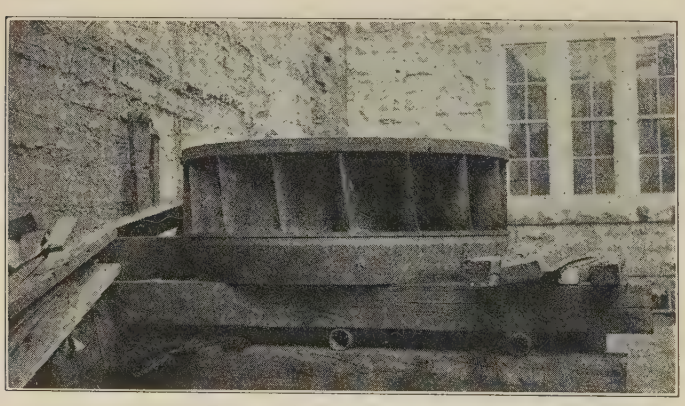


FIGURE 172. — A TURBINE.

Taken from its casing at the Trenton Falls, N. Y., plant for repairs.

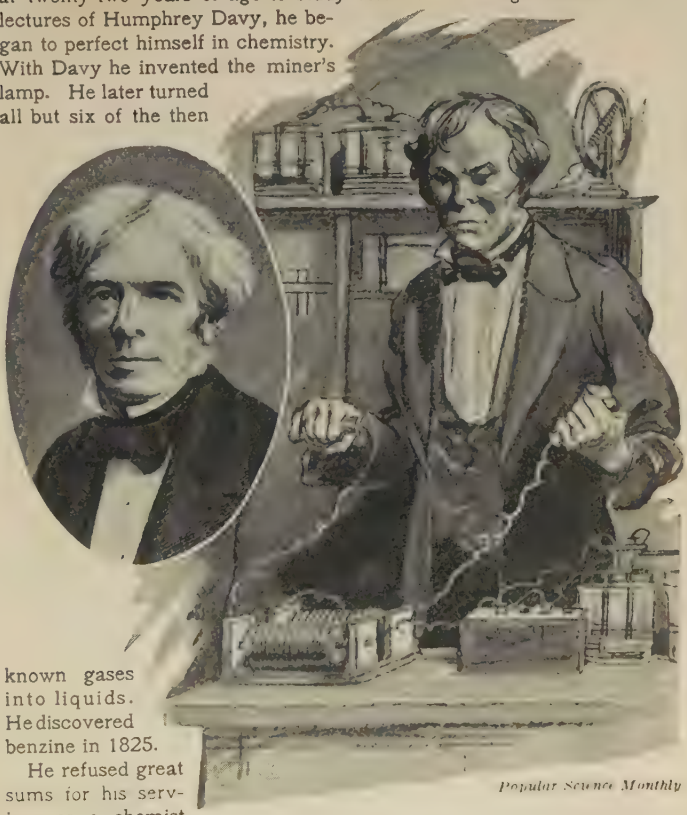
At Niagara Falls 14 turbines are used, each supplied with a 9-foot penstock[1] with a fall of 140 feet, and each producing about 13,000 h. p. or 180,000 h. p. for the whole plant. At Keokuk, Iowa, the turbines develop 300,000 h. p. and supply St. Louis, 144 miles away, with power. A small but typical plant of this kind is situated at Trenton Falls, N. Y. It has 7 turbines, each 4 feet in diameter, with a fall of 265 feet and a pressure of 110 pounds to the square inch. It generates 40,000 h. p. and supplies, over a high tension line, 28,000 kilowatts of electricity to the city of Utica, 18 miles away.

288. Water Power and Industry. — Fuel has been used so extensively because it could be carried where it was needed.

[1] Penstock: a large steel pipe enlarged at the bottom to contain the turbine wheel. Water falling through the pipe is carried directly against the blades of the turbine, causing it to revolve at from 100 to several hundred revolutions per minute.

Michael Faraday (1791–1867)

The son of parents in lowly circumstances, this young man was anxious at twenty-two years of age to study science. An eager listener to the lectures of Humphrey Davy, he began to perfect himself in chemistry. With Davy he invented the miner's lamp. He later turned all but six of the then known gases into liquids. He discovered benzine in 1825.



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He refused great sums for his services as a chemist to industrial leaders, because of his great desire to add to human knowledge.

In 1831 Faraday astonished the world by his wonderful discoveries in the field of electricity. He found out after ten years of experimentation that whenever the lines of a magnetic field are made to cut across an electric conductor, a current of electricity is set up in this conductor. From this discovery came the invention of the dynamo, the motor, the induction coil, the transformer, and the X-ray.

Ten years later Faraday broke down physically and was pensioned by the English government. A true gentleman, quiet, serious, gentle, he is rightly described in his epitaph: "Just and faithful knight of God."

Joseph Henry (1799–1878)

Born in Albany, N. Y., in 1799, Henry lived on the edge of the frontier where life was simple and the encouragement for scientific study almost entirely lacking. His earliest interest was in dramatics, but one day by chance he found a book on Experimental Philosophy. This book, which changed his whole life, he preserved to his dying day. "It was the first book," he said, "that I read with attention. It opened to me a new world of thought. It fixed my mind on the study of nature and it made me resolve to devote my life at once to the gaining of knowledge."

Henry specialized in mathematics, in physical science, and in medicine. He began to write articles on mechanics and attacked many new problems. He soon became known for his work in electromagnetism. He showed especial skill in constructing apparatus for lifting great weights by magnetic attraction. This was the beginning of the modern electric lifting crane.

The idea for the present telephone bell came from his mind. The work of Morse was based upon his discoveries. By 1831 he was the foremost experimental scientist in America. He later became the first secretary of the Smithsonian Institution at Washington, which position he held until his death in 1878. He may be called one of the great pioneers of science. Other men built upon the foundations which he laid.

But to-day the energy of falling water can be harnessed, carried for 200 miles or more, and transformed again into mechanical energy or motion to do the world's work.

6. The Most Efficient Worker — the Dynamo

289. The Electric Generator or Dynamo. — If a wire is made into a loop (Fig. 173) and made to revolve between the ends of a " U " magnet, a current of some force will be generated. This current, strange to say, will run along the wire in one direction during one half turn of the wire and

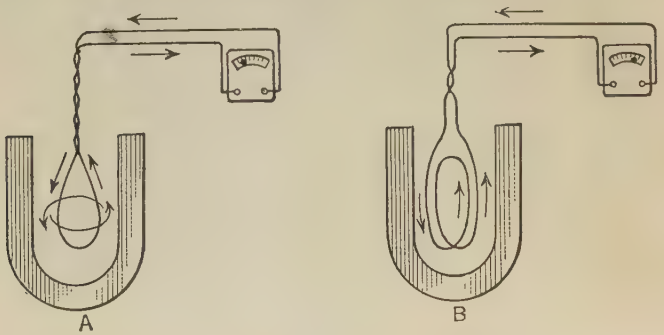


Figure 173. — Faraday's Experiment.

Note the effect of one loop of wire revolved between the magnet poles on the galvanometer. Compare this with the effect of two loops of wire on the galvanometer. Explain the difference.

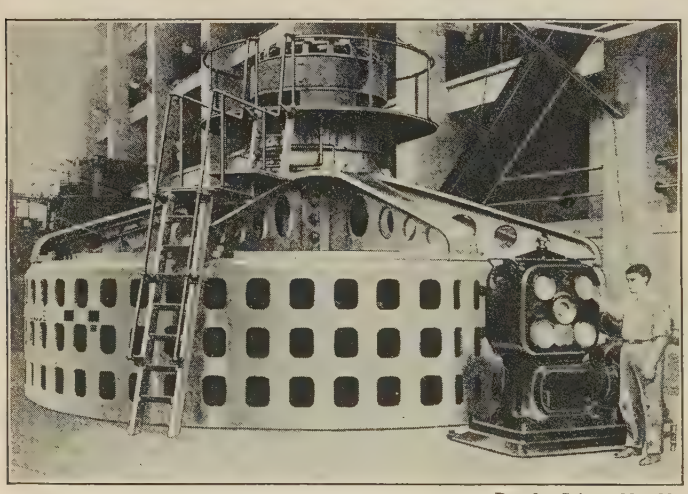
in the opposite direction during the other half turn of the wire. It thus follows that the current alternates or reverses its direction once in every complete turn of the loop. This current, as it is generated, may be carried off on a wire in contact with the coil. This peculiar action of an electric current as it is being generated is found in all dynamos,[1] no matter how simple or complex they may be (Fig. 174).

The above gives you some fundamental principles originally discovered by Michael Faraday, the Irish scientist. These

[1] Dynamo: a machine for generating electricity.

principles are now applied in every power plant and in almost every home in the country.

The essential parts of a dynamo are: (1) a rotary coil, called the armature, (2) a stationary magnet, and (3) an outlet for the current as it is generated. The armature generates an alternating current[1]



Popular Science Monthly.

FIGURE 174.—A MODERN DYNAMO.

The largest dynamo in the world. What do you suppose causes it to revolve?

which is used for heat, light, and power. The frequency of these alternations, usually about 60 per second, prevents any flicker in the electric light bulb. The frequency depends upon (1) the number of coils of wire composing the armature, and (2) the speed of its rotation. Alternating currents are often changed to direct currents for the purpose of charging storage batteries, electroplating, and electrotyping. Direct currents may also be used for heat, light, and power where it is not necessary to "step down" the voltage. A commu-

[1] Alternating current: an electric current which reverses its direction of flow at regular and frequent intervals. The flow in one direction is equal to that in the other. Two complete impulses, one in each direction, form a *cycle*. The number of cycles which occur in one second determines the *frequency* of the current.

tator is used to change the alternating current in the armature to a direct current in the external circuit. Figure 175 shows how an alternating current (A. C.) is changed to a direct current (D. C.)

290. Transforming Electric Currents. — Electric power is generated in the power house at high voltage. Before it runs through the lights in your home, it must be reduced or "stepped down" to prevent the burning out of your circuit. This is done by *transformers* which may be seen often in the

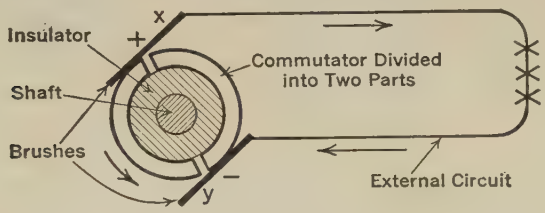


FIGURE 175. — A COMMUTATOR.

A simple device for changing alternating current (A.C.) to direct current (D.C.). The two halves of the commutator are insulated from one another and the shaft. A brush always touches each half. The + brush leaves the positive segment and the − brush leaves the negative segment at the instant the current alternates or reverses in the coil. Brush **x** is still a + brush and **y** is still a − brush and they always remain so. The current is thus kept direct. Explain.

form of large boxes fastened to poles in small cities or in the country. Again, when an electric current is carried long distances its voltage must be increased. This also is done by many large transformers placed near the power house.

The power generated at Niagara Falls is stepped up to 60,000 volts and transmitted to Rochester and Syracuse, the latter 160 miles away, to be used in running the street cars. It is stepped down in these cities to about 110 volts for use in the homes. At Big Creek, California, 80,000 horse power are stepped up to 150,000 volts over aluminum cables 241 miles to Eagle Rock where transformers step them down to 15,000 volts for Los Angeles and 6000 volts for Riverside. In all, this current travels 320 miles.

291. How Electric Current Does Work. — To do work, electrical energy must be transformed into mechanical energy

or motion. This is done by the motor (Fig. 177, A), into which electric current is delivered, causing an armature [1] to revolve. This armature may be connected to machinery by a belt. In the generator the current is developed and carried out. The current is sent into the motor causing it to revolve. The motor causes some machine to revolve. The generator is driven by a turbine turned by falling water. The generator delivers power to the motor, the motor turns machinery, which in turn does work. Thus we can follow the sequence of events from the time water falls as rain until its energy is used in the production of a pair of fine shoes. Explain fully.

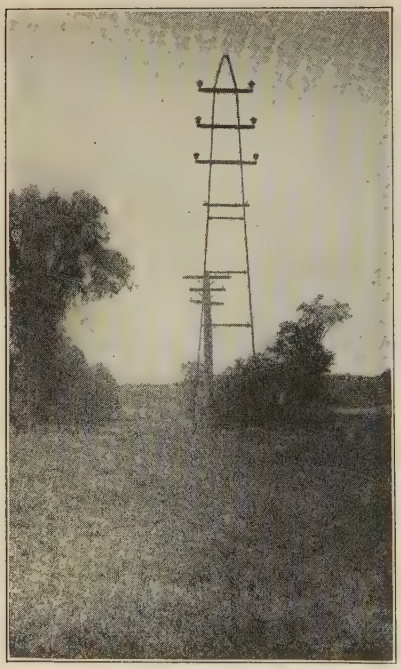


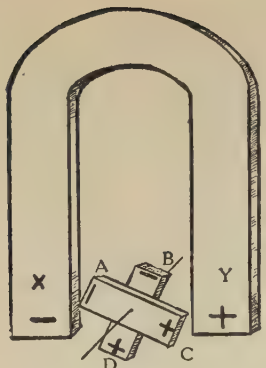
FIGURE 176. — A HIGH TENSION ELECTRIC LINE.

This line carries high voltage electric current from Trenton Falls, N. Y., to Utica, N. Y., where it runs the street cars and many factories, and lights the city.

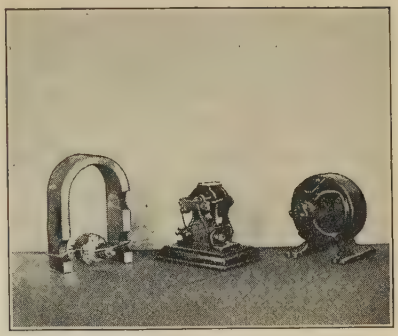
292. Electric Units. — Electricians use units of measure in dealing with electrical currents just as carpenters use a foot rule. Electrical pressure (electromotive force) is designated in *volts* [2] so named in honor of Count Volta, a great Italian scientist who lived from 1745 to 1827. A dry cell unit

[1] Armature: an iron core wound with wire which revolves about the field of the magnet or vice versa.

[2] Volt: the unit of electrical current pressure on a wire.



A



B

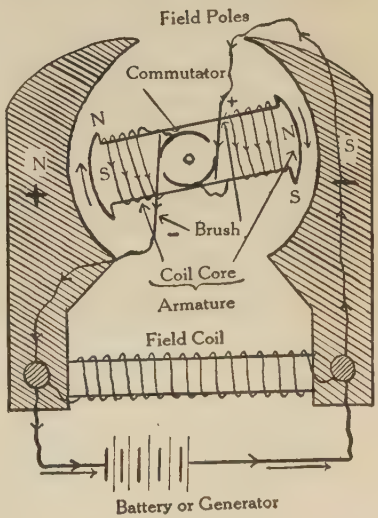
FIGURE 177. — THE PRINCIPLE OF THE SIMPLE MOTOR.

A. **A** and **B** are attached to each other. Why? Why does **Y** repel **C**? Why must **D** be changed from + to − when it turns a little farther to the left? What will happen to **C** as it rises? What effect does **X** have on **D**?

What device can change the polarity of the moving part in this motor?

B. Find the armature in each.

C. Note the electromagnet on a pivot between the permanent poles of the field magnet. The wire coil is wound from end to end and the two free ends are connected with the two halves of a split brass ring or commutator (Fig. 175). When current is sent into the field magnet and also the armature through the brushes, the electromagnet begins to revolve. Why? With each half turn of the armature, the + brush leaves one segment and comes into contact with the other. At once the current in the armature *reverses its direction.* Each armature pole becomes the same as the field magnet pole next to it. They will repel each other for a half turn until the current is again changed. Thus the armature keeps revolving and the current changing its direction. What device causes the changing?



C

will produce a little more than one and one-half volts. The ordinary voltage on an electric wire in the house is 114 volts, not enough to kill one but enough to give him a severe shock. To the unit amount of current which passes a given point in a wire in one second we give a name. We say the current has the strength of 1 *ampere* (ăm-pâr'),[1] so named in honor of a French scientist, André Ampère, who lived from 1775 to 1836. The average 60-watt tungsten bulb uses $\frac{1}{2}$ ampere; an electric bell uses about $\frac{1}{10}$ ampere. Fuses are made to carry from 6 to 30 amperes for ordinary purposes.

The amount of current going over a wire depends upon the size of the wire. The smaller the wire, the greater the resistance and the greater the resistance, the less the current and amperage. The unit of measure used to determine resistance is the *ohm*[2] (ōm), so named in honor of Georg Ohm, a German scientist who lived from 1787 to 1854. The ohm is the resistance to a current made by 160 feet of No. 18 copper wire, ordinarily used for lamp cords. From the relations which naturally exist between volts, amperes, and ohms, Ohm in 1826 developed what is known as Ohm's Law, which can be shown as follows:

$$\text{Current} = \frac{\text{electromotive force}}{\text{resistance}} \quad \text{or} \quad C = \frac{E}{R}.$$

$$\text{Amperes} = \frac{\text{volts}}{\text{ohms}}.$$

$$\text{Resistance} = \frac{\text{electromotive force}}{\text{current}} \quad \text{or} \quad R = \frac{E}{C}.$$

$$\text{Ohms} = \frac{\text{volts}}{\text{amperes}}.$$

$$\text{Electromotive force} = \text{current} \times \text{resistance or } E = CR.$$

$$\text{Volts} = \text{amperes} \times \text{ohms}.$$

The above formulas are constantly used by all men who do electrical work.

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[1] Ampere: the unit of electrical current on a wire.

[2] Ohm: the unit of resistance of a wire to electrical currents.

293. Steam, Gas, and Water Power Plants. — A final comparison between the steam, gas, and water power plants will show striking differences. In the water turbine there is no heat except that generated by friction, which alone prevents the turbine from being an almost perfect machine.

Thousands upon thousands of men are now engaged in the work of mining, transporting, and feeding fuel to the flames in our steam plants. In the water power plant a half dozen men can easily do all the work of controlling the turbines and regulating the dynamos. The increase in efficiency is quite marked. With the factories of the country running on electrical energy we shall be using the energy of the sun almost directly. Explain.

REVIEW OUTLINE

1. Industry: Meaning; how it began; the early home the center of industry; transfer to the factory; the rise of towns and cities.
2. Industry Based upon: (1) energy and (2) work.
3. Sources of Energy Used in Industry: (1) Animal (from foods); (2) motion (from burning of fuels); (3) electrical (from falling water). All energy has its source in the sun.
4. Use of Heat Energy in the Reduction of Ores: Smelting; production and use of pig iron.
5. Production of Steel by: (1) Bessemer process; (2) open hearth furnace; (3) electric furnace. Composition and kinds of steel. Tempering.
6. Melting and Fusing of Iron and Steel: Welding and cutting steel plates. Principles involved.
7. Importance of Power from: (1) Heat; (2) animals; (3) water.
8. The Steam Engine: Nature of steam. Early engines (Newcomen, Watt). Modern steam engine. Relation to the work of the world.
9. The Gas Engine: How gasoline and air explode in the presence of heat. How the gas engine works. Comparison with steam engine. Relation of power to the gas and coal supply.
10. The Importance of Water Power: Sources of water power. Comparison with cost of steam power. Types of water wheels (Pelton, turbine).

11. How Water Power is Made Available through use of: (1) Dynamo; (2) transformer; (3) motor.
12. Electrical Units: (1) Volts (Volta); (2) amperes (Ampère); (3) ohms (Ohm). Meaning of each. Ohm's Law; how used.
13. Comparative values and cost of steam, gas, and water power in industry.

SUMMARY

All work among early peoples was done by *hand*. When men discovered the possibility of making the sun do work for them by using the waterfall to cause a wheel to revolve and run a mill, industry began. Then communities grew up along rivers and varied industries gradually developed. The source of energy used in industry may be in the muscles of men or of beasts, in petroleum, in coal and other fuels, or in water power.

Underlying all industries is one particular industry — the *mining* and *reduction of ores*, the *refining of iron* and the *tempering of steel*. With iron and steel molded or rolled into engines and machinery, with power to run these engines and machinery, the complex industries of to-day are possible.

The *steam engine* was the first kind of device to produce much power. To-day it does most of the work of the world. *The gas engine*, a later development, because of its lightness and efficiency, has become the greatest factor in short-distance transportation. The recent return to the use of *water power* on a large scale is of great importance because of the increased scarcity and cost of fuels. The harnessing of water power or "white coal" by the use of *dams* and *turbines*, which generate electric current by revolving *dynamos*, makes it possible to transmit this power over wires to distant points where it is adapted to the needs of the homes or street lighting. By means of *motors* it is used to run machinery or to propel vehicles.

The *pressure* and *rate of flow* of electric currents are measured in *volts* and *amperes*. The *resistance* to the current is measured in *ohms*. You should always remember, however, that in every case, the power used can be traced back to the *sun* as the source of all energy.

Remember that:

1. All energy comes from the sun.
2. The greatest factor in the development of industry was the invention and improvement of the steam engine.

3. Modern industry was impossible until men had learned to reduce ores and refine iron into steel.

4. The most economical use of heat energy is through the modern gas engine.

5. The industry of the future will, in all probability, depend entirely upon water power.

THOUGHT QUESTIONS

1. What advantages has electric power from central stations over individual steam power for factories?

2. What is the composition of iron ore and why can it not be used in industry until refined?

3. Why do iron-producing companies employ expert chemists?

4. What does the blast furnace do to iron ore?

5. What are some of the characteristics of pig iron?

6. What changes take place in pig iron when it is changed to steel?

7. Where does the energy that runs your watch come from?

8. In what part of the country is there found the greatest amount of water power? Do you find much manufacturing in this region? Explain. What has caused a partial scattering of factories away from these falls?

9. What made New England such a manufacturing center?

10. Show how the steel industry is essential to the production of power and the use of it in manufacturing of all kinds.

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Darrow. Boy's Own Book of Science. The Macmillan Co.

Fisher. Resources and Industries of the United States. Ginn and Co.

Husband. America at Work. Houghton Mifflin Co.

Vulte and Vanderbilt. Food Industries. Chemical Publishing Co., Easton, Pa.

Williams. The Wonders of Science in Modern Life. Vol. 1 and 4. Funk and Wagnalls Co.

Williams. How It Is Done. Nelson.

Williams. Romance of Modern Inventions. J. B. Lippincott Co.

KEY PICTURE 12A. — EARLY TRANSPORTATION.

Above: An early steam locomotive. Compare with Figure 180 and explain the difference.

Below: Henry Ford at the age of 30, in his first "horseless carriage." Compare with Figure 185. Account for the difference.

CHAPTER XII

THE WORK OF THE FACTORS OF OUR ENVIRONMENT IN TRANSPORTATION

A. TRAVEL ON LAND

There's a big resounding whistle on the engine when it toils —
None thinks about the water as it bubbles and it boils —
There is buzz and there is bustle and the people love to gaze
As the prodigy goes onward in its unresisted ways.
We quite forget, while watching all the beauty of the scheme,
That somewhere out of sight is pent the mighty force of steam.
But despite this lack of splendor, 'tis agreed by men of wit
That if the steam were wanting the machinery would quit.

— The Washington Star.

Can You Tell Just How a Steam Engine Works?

Try it. It will be a good test of your knowledge and your ability to make things clear. After this is done, try to tell how an automobile engine works. This will test your knowledge fully. You may have to get help here from the garage man. Then, how much do you know about the motor in the electric fan or the washing machine? Mighty little. Well, you can learn much about these things if you really want to. Again, good roads have come as a result of the automobile. Did you ever think of this? How are roads made? Why are good roads "good"? Suppose you study something about roads, curves, bridges, reduction of friction, and other phases of transportation in this chapter.

Some Practical Questions :

1. What can a steam engine do with energy?
2. Why is a gas engine more efficient than a steam engine?
3. Why is the movement for good roads in this country a wise one?
4. Why is the electric motor lighter and more efficient than a gas or a steam engine?
5. Explain why many people believe that all transportation will be by electricity in the near future.

Home Problem. — Secure, if possible, the use of a toy engine which runs upon tracks. Run the engine alone and coupled to its cars. Compare its speed when running on a straight track with that on a curve. Raise the tracks at some point and note its effect upon the speed of the train. Find a grade which does not materially interfere with the speed of the engine and determine what per cent grade this is. Determine some of the difficulties engineers have to meet in building railroads.

Field Problem. — Visit a car shop or a railroad station and watch several engines as they come in. Try to identify all the parts as shown in the drawing on page 346 and learn their uses in the mechanism. Report to the class your findings.

1. Early Methods of Travel on Land

294. The Earliest Means of Travel. — It is thought that the "pole drag" must have been the most common early means of carrying burdens used by the American Indians in their travels from place to place. (Study Plate III.) The pole drag was really a wheelbarrow without wheels. Explain. Then came the wheel and axle.

It is supposed that the Sumerians (sū-mē′rĭ-ănz), who lived along the Euphrates river more than 5000 years ago, used wheels to draw loads. These solid wooden wheels were a vast improvement over the drag. Speed was at once increased, friction was reduced, riding was made somewhat of a pleasure, and trading and commerce were increased. Explain each advantage. Name two places where friction occurs in the wheel and axle. How can it be reduced in each place? How can a wheel be prevented from cutting into a soft roadbed?

The Egyptians (ē-jĭp'shăns) used the wooden cart (Fig. 178) to draw the stone blocks to the place where the pyramids were built. They probably used a roller to bring the blocks to the top of the pyramid. They used levers to get the blocks into place. It was a long step from the roller and the ox cart to the steam locomotive. (Study Plate III.)

FIGURE 178. — AN ANCIENT OX CART.

Note the solid wooden wheels and the crude frame and tongue. This kind of cart was the first great advance over the pole drag. Why?

2. THE STEAM LOCOMOTIVE

295. The Earliest Locomotives. — The story of the development of the steam locomotive reads like a novel. The great locomotives of to-day are not the work of one man and never could be, because the span of one man's life is not great enough to insure the perfection of any epoch-making invention. Watt, Newcomen, Stephenson are the names most commonly connected with the steam engine. Trevithick built a steam carriage in 1801 and a steam railroad engine in 1804, both doing powerful work. In 1826 John Stevens, in America, built a model locomotive. Stephenson built his railroad engine, called the Rocket, in 1829 and scored a success with it (Key Picture 12a).

296. Later Models. — Stephenson's engine brought the power to act directly upon the drive wheel and the most perplexing problem of steam locomotion appeared to be solved. The steam chest and cylinders were placed on the sides of the

boiler near the front and by means of a connecting rod a direct drive could be made on the drive wheels and tremendous power utilized.

The size of the engines did not change much for many years because it was thought that the limits of power had

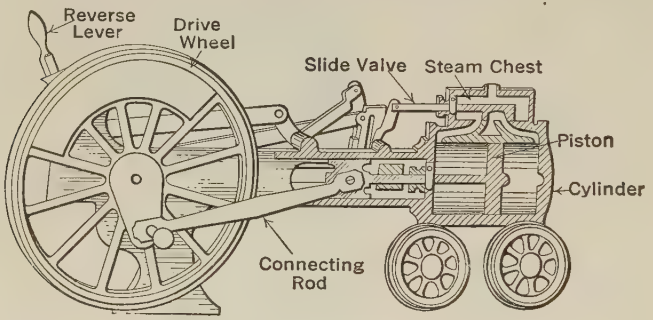


FIGURE 179. — MODEL OF A STEAM LOCOMOTIVE.
Compare with Figure 166. What is the use of the reverse lever? Explain just how the moving parts work.

been reached and that, therefore, the weight must be kept down. These locomotives were awkward-looking affairs, with tall and broad smokestacks. It was not until 1895 that marked changes in construction were made and since

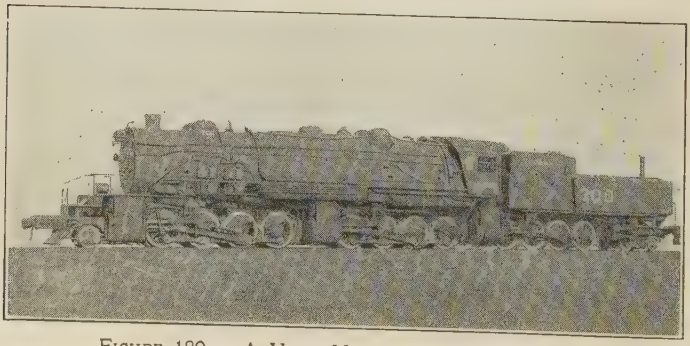
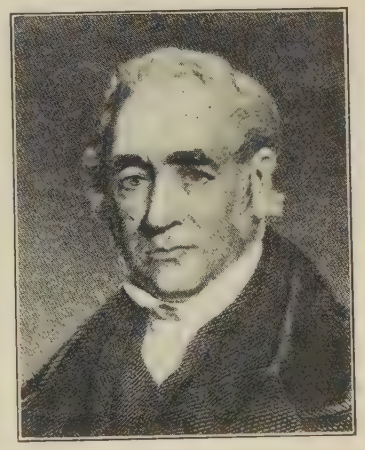


FIGURE 180. — A HUGE MODERN FREIGHT-ENGINE.
Count the number of drive wheels. This has a tremendous drawing power. How does its weight help it?

George Stephenson (1781–1848)

George Stephenson stands out as one of the world's greatest inventive geniuses. This man in the beginning of the nineteenth century took the inventions of his predecessors and combined them into a steam locomotive which worked.



In 1821 he built a railroad 21 miles long. In 1829 after overcoming great difficulties, his locomotive, the Rocket, won the first prize in a contest in England by carrying 36 passengers at a speed of 39 miles an hour.

Stephenson soon became a world authority on steam locomotives. He may be truly called the father of steam transportation. He died in 1848, the foremost genius in the devising of ways to make steam do the work of man. Every mile of the hundreds of thousands of miles of railroad forming a close network across the United States to-day is a monument to Stephenson's perseverance and inventive genius.

that time the size and complexity have enormously increased. Study with care Figures 179 and 180 and be able to explain how the locomotive works.

297. Source of Steam Power. — How can steam do so much work? Steam is vaporized water and as such is an invisible gas. No one has ever seen live steam. When it escapes, it condenses into clouds of visible droplets of water and is "dead," having lost all its power to do work. As you have already learned, one pound of water which occupies about .016 of a cubic foot of space, can expand into steam occupying 26.7 cubic feet of space and exerting enormous pressure. This means that the boiler in which steam is generated must be extremely strong to resist this pressure. In a properly built and controlled boiler, the steam, as generated, is sent into the cylinder where it at once expands and uses up its own heat in becoming cool and in pushing the piston back and forth. This results in rotary motion in the drive wheels, and they haul the train. Thus work is done by the expansion of steam.

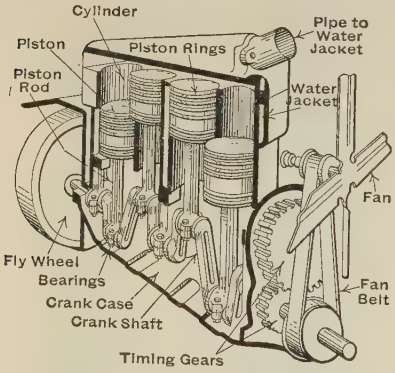


FIGURE 181A. — A FOUR-CYLINDER AUTOMOBILE ENGINE AS SEEN FROM THE SIDE (INTERIOR VIEW).

Note the position of each piston. Explain.

3. THE AUTOMOBILE

298. The Four-Cylinder Gas Engine. — Several different movements must take place at the same time in a four-cylinder gas engine before explosions can occur in regular succession. To keep an engine moving there must be an *explosion*, or *power* stroke, a forcing out (stroke) of waste gases

or *exhaust* stroke, an *intake* (stroke) of new gases, and a *compression* (stroke) of gases. How can all these actions be accomplished in order and with efficiency? (Fig. 181a).

As these four actions named above are all occurring at once, each one in a different cylinder, it follows that in any one cylinder they must all occur in order and in a given time. That is, any one cylinder must take in gas, compress it, explode it, and exhaust the burned-up gases. But while

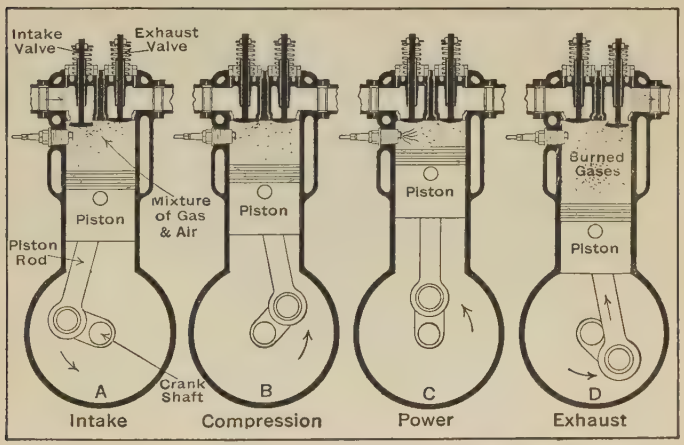


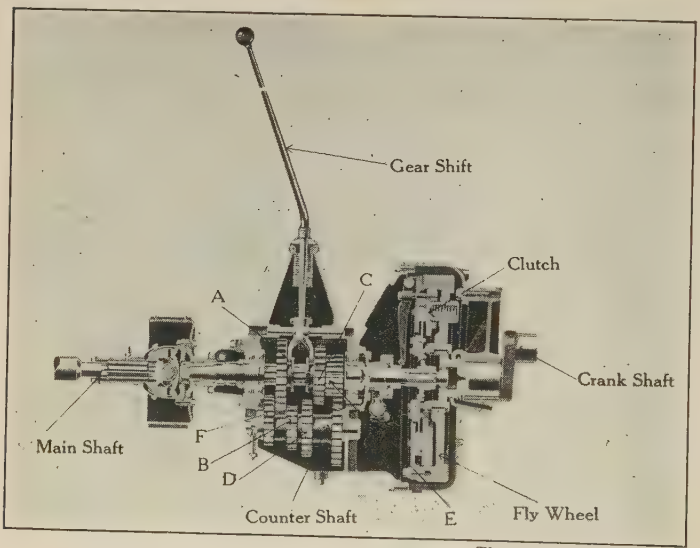
FIGURE 181B. — THE INTERIOR OF THE FOUR CYLINDERS SHOWING PISTON MOVEMENTS.

Explain how each piston works.

this order is the same in all cylinders, the operations must occur at different times for different cylinders. In each cylinder the piston moves two times each way between each two explosions in it. It takes four strokes to produce a power stroke. For this reason such an engine is called a four-cycle engine. Suppose you follow each of these strokes as illustrated in Figure 181b and find out just what does happen in a cylinder during the four cycles.

299. Cooling the Cylinders. — In the steam engine, the early problem, at least, was to keep the cylinder hot. In the

gas engine, the problem is to keep the cylinders cool. Because the combustion of fuel is inside of the cylinders themselves, the heat developed in them is terrific, often exceeding 3000° F. If this heat is not kept down, the piston heads may swell,



The Studebaker Corporation.

FIGURE 182A. — THE TRANSMISSION, WHICH CONNECTS THE ENGINE WITH THE DRIVE SHAFT.

Except in third speed, the crank shaft is separated from the main shaft between **C** and **E**, and the power passes from one to the other only through the countershaft. The gear wheel **E** and the one below it are in constant mesh. **D**, **B**, and **F** are fixed gears on the countershaft.

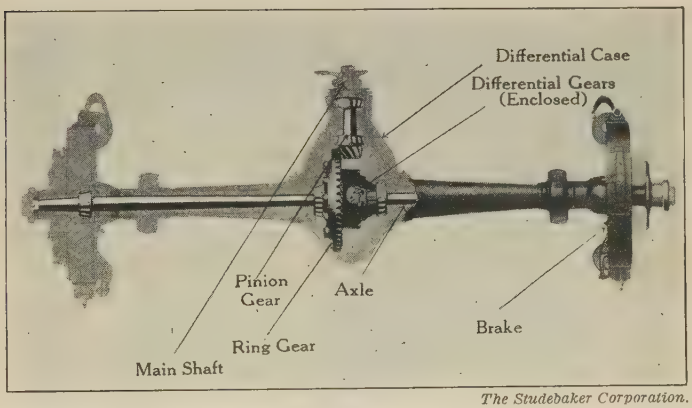
In first gear or *low*, the gear **A** is engaged with **B** on the countershaft. The forks of the gear shift lever cause the gear wheels to slide forward or backward. *Second* speed results when **C** and **D** are engaged. *Third* or high speed results when **C** slides over the smaller part of **E**. For *reverse* **A** is shifted back and engages with the small gear a little above and beyond **F**. Now explain the shifts on the picture without use of this explanation.

stopping the engine, or the bearings may be burned out, necessitating large and costly repairs.

The several methods of cooling are one in principle. Oil is pumped about the bearings and water is pumped about the

cylinders. The water is sent through a radiator, where it is quickly cooled by the cool air drawn through the radiator by the rapidly revolving fan. Some engines are air-cooled by means of large fans which drive air through honeycomb cells about the cylinders.

300. The Gas Engine and the Automobile. — The stationary gas engine was finally placed upon a carriage and so geared to the wagon wheels that the " to-and-fro " motion of



The Studebaker Corporation.

FIGURE 182B. — THE DIFFERENTIAL, WHICH CONNECTS THE MAIN SHAFT WITH THE REAR AXLES AND DRIVE WHEELS.

The pinion gear of the main shaft is enmeshed with the ring gear which is rigidly fastened to the left axle. By means of differential gears having independent motion (not seen here because enclosed), motion is transferred to the right axle in such a way that either wheel can move at a different speed than the other when going around corners. Thus the differential differentiates the speed of the rear wheels.

the piston was changed into rotary motion and the wagon was caused to move forward or backward. This was known as the " horseless carriage " and we now know it as the *automobile*. It was at first a very crude affair and each one sold was provided with a coil of rope to be used in hauling it home, as most of them broke down on nearly every trip (Key Picture 12a).

The modern automobile, however, as a result of many improvements, has become a very complex mechanism. It may now be said to be composed of several systems. (1) The chassis (shȧ'sē), including the wheels, frame, springs; (2) the body and its attachments (Fig. 185); (3) the power plant, or the engine and its parts (Figs. 181a and 181b); (4) the transmission system, which connects the engine with the driving wheels (Figs. 182a and 182b); (5) the cooling system (Fig. 183); (6) the electric system, which causes the engine to start and keeps it running (Fig. 184); and (7) the control system, which causes the car to start, increase its speed, stop, and reverse. This system also includes the steering apparatus. Study the diagrams showing these systems and be able to explain each of them.

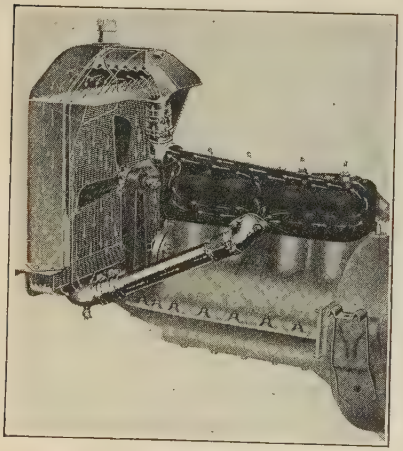


FIGURE 183. — THE FORD COOLING SYSTEM. Account for the direction of the arrows.

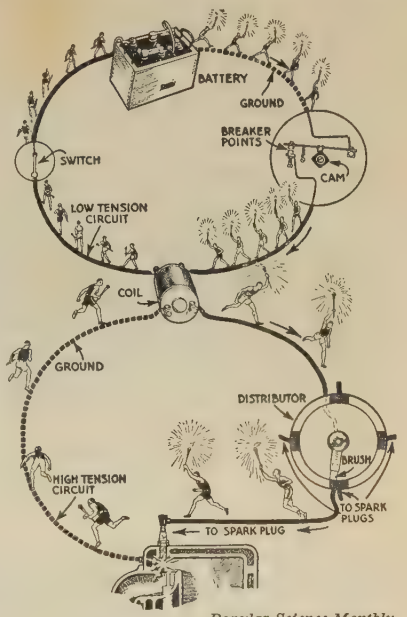
301. The Automobile and the Work of the World.—The automobile is used for every conceivable purpose. Beginning as a novelty, then used as a pleasure vehicle, it is now used to haul freight over long distances to every part of the country. In 1895 there were 300 automobiles in the United States; in 1902 there were 29,000; in 1922 there were 12,000,000 and in 1925 there were 15,280,000. The automobile is fast taking the place of the trolley car in our city streets and on some railroads it is being used directly upon the rails to take care of short-haul traffic (Figs. 185 and 186).

Its speed and easy control make it of tremendous value.

A little whiff of gas and air can be exploded and so much power generated that a vehicle weighing tons can be sent over the road at great speed.

4. The Electric Motor

302. The Electric Motor. — You have already learned that a dynamo is a mechanism for changing motion into electrical energy or power. But this electric power cannot be used unless it is changed again into motion. The electric motor does this work of changing electricity into motion. A motor is built on essentially the same plan as a dynamo. Armatures, permanent magnets, and commutators are found in both. Study very carefully the parts of the motor pictured in Figure 177 and read the description underneath the picture until you understand how it works. Then secure a small cheap motor, study its parts, and see how it works. Finally, take it apart, assemble it again, and see if it will run as before.



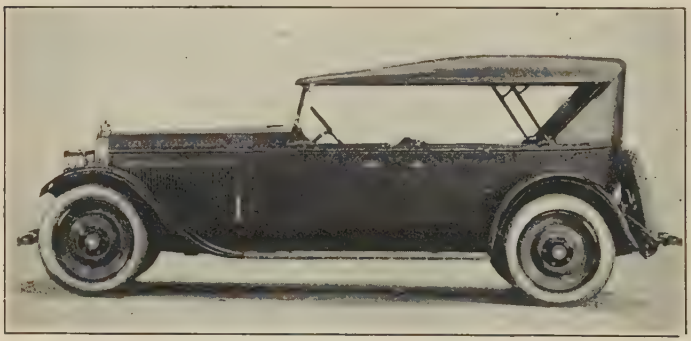
Popular Science Monthly.

Figure 184. — The Ignition System.

Study the little men. What does the coil do to them? the battery? the spark plug? When does the spark plug fire? Trace the electric circuit and explain it.

303. Commercial Motors. — In practice, motors are not as simple as the one shown in our diagram (Fig. 177). A motor of such simple structure would supply uneven impulses of power because the force between its armature and field would not be constant. So, instead of one electro-

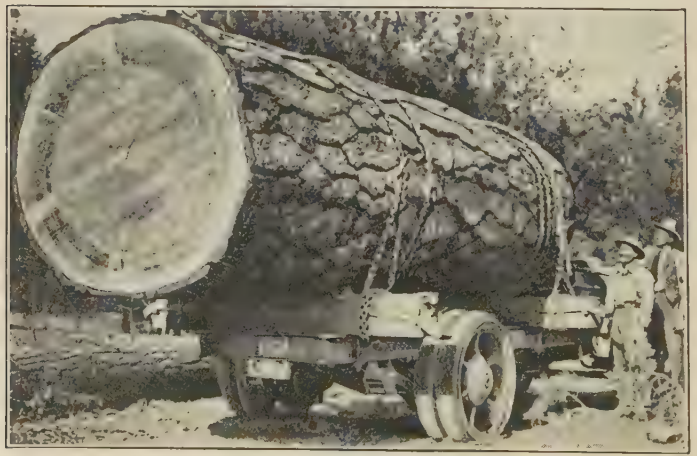
magnet, the armature may consist of four or even a dozen, wound with miles of wire all revolving on the shaft. This requires, of course, a commutator of many parts and a very finely adjusted set of brushes. But the principle is



Popular Science Monthly.

FIGURE 185. — A MODERN PLEASURE CAR.

Compare with Ford's first car (Key Picture 12a). What are the likenesses? the differences? Explain.



Popular Science Monthly.

FIGURE 186. — A MODERN FREIGHT CARRIER.

Note the size of the log. To carry it is play for this truck. Explain.

the same, whether in a toy motor, or in one weighing tons like those now commonly used in the electric locomotives which draw heavy trains. (Plate III and Fig. 188.)

304. How the Trolley Car Works. — The current for the car may be generated miles away at a power house by water power or near by through the use of steam. Explain this. (Study Plate III and Fig. 187.)

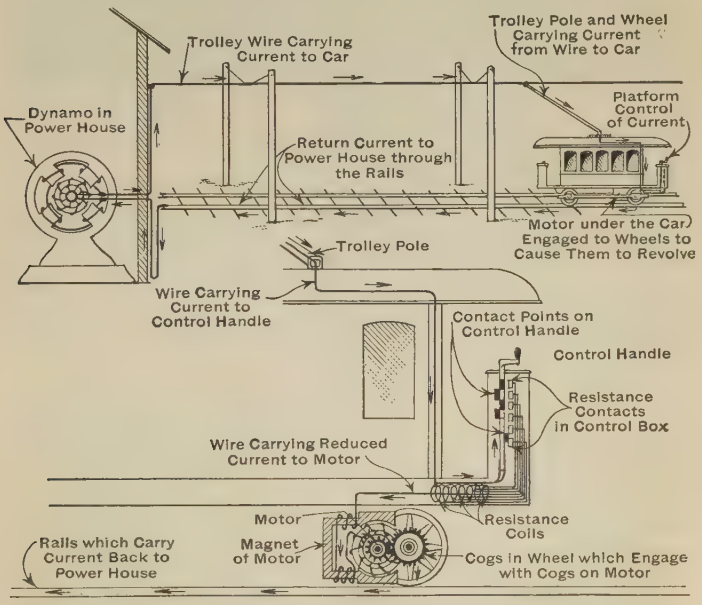

Trolley Wire Carrying Current to Car
Trolley Pole and Wheel Carrying Current from Wire to Car
Dynamo in Power House
Platform Control of Current
Return Current to Power House through the Rails
Motor under the Car Engaged to Wheels to Cause Them to Revolve
Trolley Pole
Wire Carrying Current to Control Handle
Contact Points on Control Handle
Control Handle
Resistance Contacts in Control Box
Wire Carrying Reduced Current to Motor
Motor
Resistance Coils
Rails which Carry Current Back to Power House
Magnet of Motor
Cogs in Wheel which Engage with Cogs on Motor

FIGURE 187. — HOW A TROLLEY CAR WORKS.

What causes the car to move? How is the movement of the car controlled? What becomes of the electric current used in the car? Trace the electric current from the power house around the circuit.

This current is controlled by the motorman by means of levers on top of the control box — a reverse lever and a progressive power lever. In starting the car, the brake is released and the power lever is advanced a notch at a time, the car meantime gaining speed. At the last notch the car reaches its maximum speed. When stop-

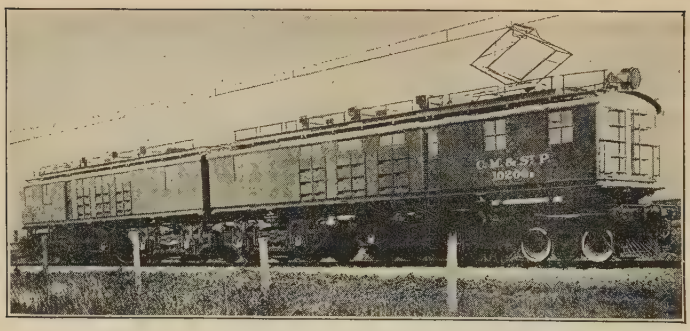


FIGURE 188. — A LARGE ELECTRIC LOCOMOTIVE.

What makes it move? Where are the motors? Where does the power come from?

ping, the power lever is turned back to its first position, shutting off the power, and the brake lever is applied. The controller does two things: (1) It starts the car, and (2) it governs the amount of electricity that goes into the motor, thus controlling its speed.

FIGURE 189A. — AN UNIMPROVED COUNTRY ROAD.

How does this kind of road affect farming? industry? What has chiefly caused the building of good roads?

The brakes are operated by air, which is compressed in strong chambers by a small motor. This brake motor may often be heard running under the floor of the car. A control lever at the car front allows some of this air to escape against the brake and the car is stopped at the will of the motorman.

FIGURE 189B. — A GOOD CONCRETE ROAD. Why is this better than that shown in Figure 189a?

305. Heating and Lighting the Car. — All electric cars are lighted by electric bulbs fed by current coming over the trolley wire. This light is often dim and irregular while the car is running. Explain. The car is heated by resistance coils placed under the seats. These coils become red hot and give off much heat through registers into the car. This is an excellent example of the transformation of energy. Explain.

5. The Importance of Good Roads, Steel Bridges, Easy Curves, and Grades in Modern Transportation

306. Roads. — The coming of the automobile has made great changes in the construction of roads (Figures 189a and 189b). In large towns and cities where the traffic is very heavy, the streets are now paved with asphalt, or wooden blocks, or concrete. In the country, concrete is now the most durable road material and is fast replacing the macadam, crushed stone, and cement roads. A concrete road is laid

down upon a bed of crushed stone (Fig. 190). It is laid in sections each containing iron rods or steel mesh to prevent warping and can be relaid easily without destroying the whole road.

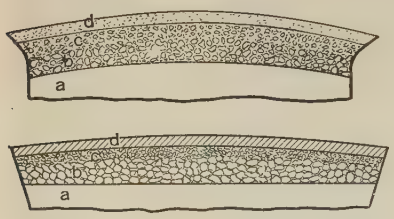


FIGURE 190. — CROSS SECTION OF MACADAM (ABOVE) AND CONCRETE (BELOW) ROADS.

Above: **a**, clay; **b**, coarse stones; **c**, small stones; **d**, sand and fine gravel.

Below: **a**, clay; **b**, crushed stone rolled together; **c**, concrete poured on wet and hardened; **d**, asphalt covering laid on tar and hardened.

Which is the better road? Give your reasons.

These roads are higher in the center than at the sides. Explain. The concrete road lasts because the older it gets the harder it gets. It also gives the best grip for tires. Explain.

307. Grades and Curves. — Grades are the big problems of road engineers. In railroads, a rise of more than two and one-half feet in every hundred feet is excessive and greatly reduces the efficiency of the road. So engineers plan to eliminate sharp grades by digging tunnels and by the use of many curves. These slow up a train, but they are less of a hindrance than a steep grade, as it takes five times as much power to draw a trainload of 1000 tons up a 2 per cent grade as it does to draw it along a level surface (Fig. 191).

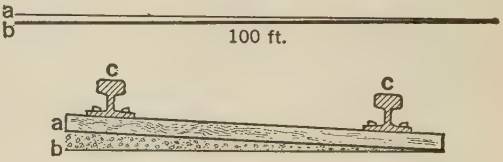


FIGURE 191. — GRADES AND CURVES.

Above: A 2% grade. Above this grade engines cannot easily go. Why?

Below: Arrangement of track in a curve. **a**, tie; **b**, roadbed; **c**, rails. Why the rise in the outside rail?

Curves on our highways and railroads are being straightened. The great increase in speed makes this necessary. Where curves on our highways cannot be greatly reduced

signs warn the drivers. Many accidents have happened on curves which had been improperly constructed. When a curve comes in a railroad the train tends to jump the track. Explain. Experience has shown that the outside rail must be considerably raised to overcome inertia and cause the train to take a new direction. Properly banked roads allow trains to keep their original speed (Fig. 191). This is a great saving in time and expense to railroads. Automobile roads are now being built with sharp curves banked.

308. Bridges. — Bridges are necessary where streams are found. They save many miles of travel in highways and railroads. Early bridges were of logs, each acting as a girder. Even to-day small streams are spanned by long beams. For longer bridges trusses must be used. A truss is a combination of beams, rods, bars, and the like, forming a rigid framework which provides support for some object.

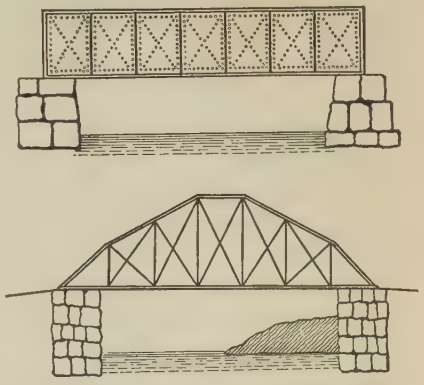


FIGURE 192. — TWO TYPES OF STEEL BRIDGE.
Above: Plate girder bridge. Why is this very strong and rigid?
Below: A triangular truss bridge. Why is this light and strong?

For extreme distances the cantilever bridge is used. Another type of bridge is the suspension. Tall towers of stone or steel support enormous cables composed of thousands of small wires bound together. From these cables steel rods hang and support the roadway. The new Bear Mountain Bridge across the Hudson River is an example of this type. This makes a most beautiful bridge (Fig. 193).

The simple arch bridge is one of the commonest and oldest

types. It is still widely used, even for very large bridges.

The future prosperity of the country will depend not so much upon new inventions as upon increased facilities in the use of our present inventions. Good roads will be one of the chief factors in the future work of the world.

FIGURE 193. — THE BEAR MOUNTAIN SUSPENSION BRIDGE.

This bridge spans the Hudson River at Bear Mountain, N. Y. Why is it called a suspension bridge?

REVIEW OUTLINE

1. Transportation Depends upon Power Generated by: (1) Animals; (2) man; (3) steam; (4) exploding gases; (5) electricity.
2. Early Locomotives: Types. Work of Trevithick, Newcomen, Watt, and Stephenson.
3. The Modern Locomotive: Essential features. Sources of steam power. Steam as a gas; expansive power; dangers.
4. The Four-Cylinder Gas Engine; Essential structure. Piston strokes.

5. Cooling the Engine by: (1) Air; (2) water; (3) oil.

6. The Gas Engine and Transportation: Early types. Seven important systems composing the modern automobile are: (1) Chassis (wheels, springs, frame); (2) body; (3) power plant (engine); (4) transmission (gears); (5) cooling (radiator, fan); (6) ignition (battery, lights, spark plugs, etc.); (7) control (steering wheel, pedals, brakes, etc.).

7. Use of the Automobile To-day in: Quick, short hauls distributing (1) freight, (2) food, (3) passengers.

8. The Electric Motor: Parts. Principle upon which it works. Commercial motors and their use in the electric car and electric railway engine. How the electric car is built, how controlled, how heated and lighted.

9. Aids in Transportation: Early roads. Kinds of roads: dirt; macadam, asphalt, concrete. Grades and curves. Bridges: kinds. Special uses for special locations.

SUMMARY

With the coming of *Trevithick*, *Stephenson*, and *Stevens*, real progress in land transportation began. *Steam* was harnessed by these men in a *locomotive* early in the nineteenth century and a limited amount of goods was carried some distance by this power, although the pace was still slow and reaching the desired point somewhat uncertain.

By a series of wonderful inventions and improvements, principally in *size*, *weight*, and *efficiency*, the modern locomotive came into use. The expansive power of steam when confined in a small space and allowed to act upon a movable *piston* connected with drive wheels changes *to-and-fro* motion into *rotary* motion. This is the principle of the locomotive. This machine was the greatest factor in the development of our country before the year 1905.

About the year 1906 the *gas engine* was perfected and placed in the " horseless carriage ," now known as the *automobile*. Its principle is simply the explosion and expansion of intensely heated *gases* within a small cylinder against a movable piston, which also changes to-and-fro motion into rotary motion.

The automobile is a complex machine using a very simple principle. Its parts are all dependent one upon the other and require knowledge and careful control by the driver. The greatest factor in the development of our country since 1906 has been the automobile.

The inventive genius of scientists has been able to generate, by means of *dynamos*, *electric currents* which can be used to do work by means of the electric *motor*. Applied to machinery in factories, to the electric car, to household appliances, and to the automobile, it has made our lives richer and more pleasant. Used in connection with railways, subway trains, and the like, it has made possible short and rapid hauls of freight and the climbing of grades impossible to the steam locomotive. It has brought the city to the country and the country to the city.

With improved engines and electric tractors and the automobile came stronger *rails*, *steel bridges*, *better roadbeds*, and *concrete roads*. Straightened roads and easy grades have added comfort and increased safety to all travel. *Good roads* are the greatest development of the last ten years in our country, because improved transportation made better roads necessary and better roads make faster and better transportation possible.

Remember That :

1. The usefulness of the modern steam locomotive is due to its great pulling or traction power.
2. The usefulness of the modern gas engine is due to its lightness and small loss of heat energy.
3. The modern automobile is the result of intense scientific experiments extending over many years.
4. The electric car is possible because electrical energy can be transferred long distances on wires and transformed into mechanical motion.
5. The present high state of development in transportation is due to the discovery of new methods of reducing friction and of checking loss of power, and to the increase in the size of the engines.

THOUGHT QUESTIONS

1. How does steam do work in the cylinder?
2. Why is sand placed upon the rails when a train is going up a heavy grade?
3. Why are the drive wheels of a locomotive weighted along a part of their edges?
4. Why is the electrification of steam railways a matter of economy?
5. What is the use of the commutator and the brushes in a motor? in a generator?

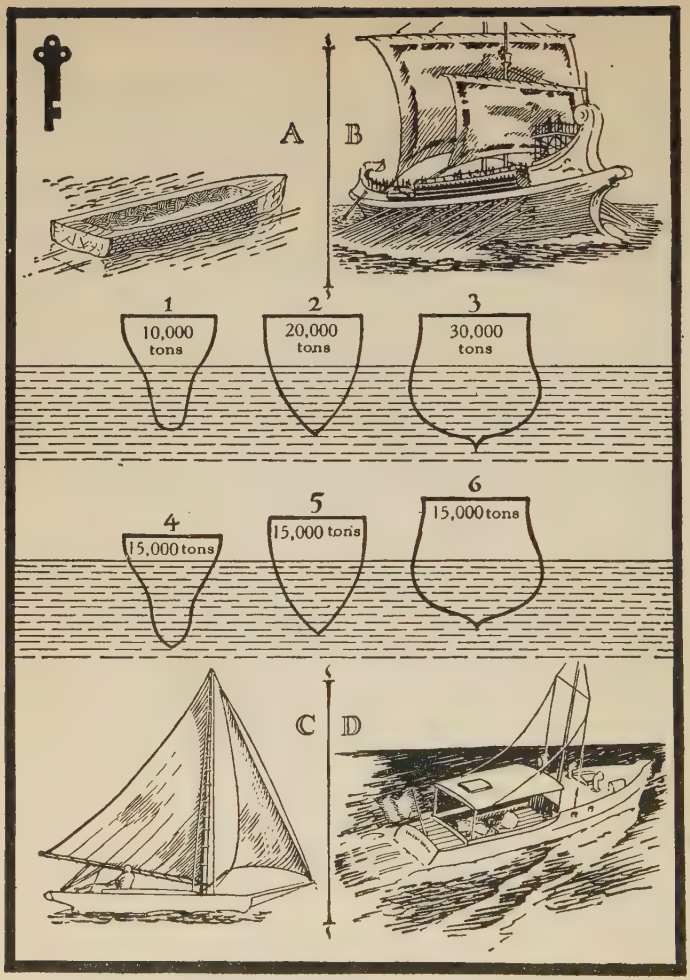
6. Mention some important differences between gas and steam engines.

7. Why do railroads tend to shorten their routes? Why do they avoid grades? Why do they prefer curves to grades?

8. How has the automobile influenced road building in the United States?

9. What is the lightest type of bridge in proportion to its size?

10. Why is the concrete road the best form of road made?



KEY PICTURE 12B. — WHY SHIPS FLOAT.

The relation between a ship's weight and its volume determines its floating capacity. The water displaced by the ship must exactly equal the weight of the ship. In the figures **1**, **2**, and **3** above, the ships vary in weight but all stand out of the water the same distance. Try to explain. Again, in the figures **4**, **5**, and **6** the weights of the respective ships are equal but displacement varies. Explain.

Tell the meaning of the four corner pictures. What are the advantage and disadvantage of each kind of vessel? Which is the best? What makes each float?

B. TRAVEL ON WATER

Ancient rocks,
My hardy bones, are rent with nitrous fire,
To rear thy marts to bridge the leaping streams
Or to usurp the ocean's olden right,
That selfish trade may dry-shod walk to power.
The very ocean, grim, implacable,
Thou loadest with the white-winged fleets of commerce.
— *George H. Boker.*

A life without a purpose is a languid, drifting thing.
— *Marcus Aurelius.*

Do You Know Why an Iron or Steel Ship Will Float?

Many people do not know how to explain the fact. In this chapter you can learn the principles which underlie boat building. Did you ever think about what makes a boat float or a piece of iron sink? Can you tell why a boat will remain upright in the water and why some small boats are safe and others unsafe? What a long history is the development of water travel! How long men traveled on water before the propeller was invented! How does a propeller make a boat go? Can you tell? How do steam and electricity send a liner across the Atlantic? Tell your neighbor how a submarine works. Here is a test of your knowledge. Try it. How does the ship captain know where he is? How is travel on the sea made safe to-day? These are questions for you to solve.

Some Practical Questions:

1. Why was early transportation on water extremely slow?
2. What discoveries made long water journeys practical?
3. Why did men think for many years that iron ships would not float?
4. Why are sailing ships going out of use?
5. Why is harbor and river improvement necessary for the proper development of water transportation?

Home Problem. — Make a simple sailboat and place it on the nearest pond. Try to sail it by fastening the sail and rudder in different positions. Learn to explain the different actions of the wind on the boat and how the boat's sail and rudder react to these actions.

Field Problem. — Learn to row and control a boat or study a motor boat and try to understand the construction and working of the engine, ignition system, propeller, and rudder. Study the balance of the boat. Report your findings to the class.

1. Early Water Travel

309. Primitive Travel on Water. — Commercial travel by water was common in the Mediterranean Sea before northern Europe emerged from barbarism, but the boats used were extremely crude. Later the Phœnicians (fē-nĭsh′ănz), who were a seafaring people, built strong ships of hewn planks spiked together and caulked with pitch. These ships, being wide and light, drew little water and were propelled by oars in the hands of slaves, arranged in banks or tiers. Such boats were called *galleys*. Later these ships were equipped with sails, which was a great step in advance as it saved labor and the feeding of many men. But all such ships had to go with the wind as they were not furnished with deep keels to allow tacking or sailing against the wind (Key Picture 12b).

With the invention of the compass, about 1250, and the improvement in managing ships, men began to venture forth into the Atlantic, and within two hundred and fifty years the world was circumnavigated.

2. How a Boat Floats and Is Made Stable in the Water

Demonstration 35: *Problem: What makes an object float in water?*

Materials: A shallow tin dish; an overflow can; a spring balance; a block of wood small enough to go into the overflow can; a 200-gram weight; and some water.

Method: *A.* Fill the overflow can with water until it overflows. Weigh the block of wood and record the weight. Weigh the shallow dish. Set the block carefully in the water of the can and allow the overflow to run off into the shallow dish. Knowing the weight of the dish, procure the weight of the overflowed water. Compare this weight with the weight of the block of wood.

B. Now fill the can with water again. Remove all water from the shallow dish. Let the 200-gram weight down into the water until completely submerged. Fasten the weight to the spring balance and weigh in water. Does it weigh 200 grams? Why? Now weigh the overflowed water. Does it weigh as much as the 200-gram weight lost in the water? Can you tell why the weight sinks?

Conclusion: Why does the wood float and the iron sink? Does the iron displace its own weight of water? Explain. Does the floating wood displace its own weight of water? Why will some objects float in water? Why does not an iron ship sink? Write this demonstration in complete form in your Science Discovery Book.

310. Why Things Float. — The very center of the problem of water travel is buoyancy. A sinking ship is worthless. Ships must float to be safe for ocean travel. No savage can tell you why a log or canoe floats but he uses the principle of buoyancy every day of his life if he lives near water. Archimedes (är′kĭ-mē′dēz) is said to have been the first man who really discovered and understood the principle of buoyancy.

Bulk is important in the floating of objects. For this reason, boat builders can compute the weight of a ship, how much water it will displace, and how deep it will sink in the water when it is launched. This allows them to paint the water-line upon the sides of the ship before it ever touches the water (Key Picture 12b).

311. Stability. — Early boats, being raft-like, sat low in the water and did not capsize when unequal weights were placed upon their decks or the cargo was suddenly shifted. But later boats built for speed were lighter and sat well up out of the water. This meant more danger of turning over;

that is, less stability. What, then, is stability? *It is the property of an object which tends to cause it to return to its first position when moved out of place* (Key Picture 12b).

312. How Stability and Safety Are Secured in Boats. — There are several ways of securing stability, but the more common are: (1) By building a boat with a wide beam (width); (2) by building air chambers in the boat; (3) by using a fixed ballast, such as rock, iron, or water; (4) by

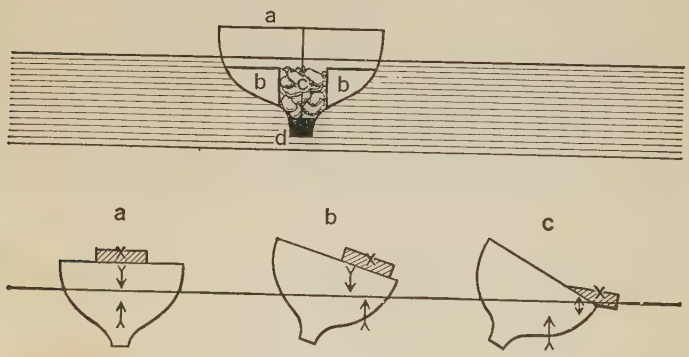


FIGURE 194. — HOW A BOAT IS MADE STABLE.

Above: **a**, deck; **b**, air chamber; **c**, ballast; **d**, weighted keel. What helps to make this boat stable?

Below: At **a** the buoyant force of the water is in line with the gravity force down. The boat is stable. Note the weight and arrows in **b** and **c**. Is the boat stable or unstable in **b** and **c**? Explain.

weighting the keel; (5) by using a center-board. The last two methods are now always used in sailboats to make them safe and allow them to sail against the wind. Explain each of the above pictured methods of securing stability (Fig. 194).

313. Sailboats. — The ancients used square sails on their merchant ships and when these were placed at right angles to the direction of the wind, they offered resistance to it. The boat, being movable, was pushed through the water, but only in one direction, — with the wind. Thus

sailors were always obliged to wait for a favorable wind before setting sail. If the wind changed, they sought a harbor or an anchorage and waited for it to change back again. They knew nothing of sailing into the wind. They could not "tack" (Key Picture 12b).

But progress in design and equipment next resulted in a type of *square-rigger* like that shown in Figure 195. The invention by an American of the *schooner* with its fore-and-aft rigging produced a type of ship which was more efficient than its predecessors because it could sail "closer" to the wind.

FIGURE 195. — A BARK.

The *Arctic Stream* becalmed off Cape Horn. Was this ship safe? Why was it slow? Why was it a great step in advance over the ancient boats?

314. The Floating of Iron Ships. — The time came when ship builders began to look for a material that was stronger than oak for the hulls of ships. Iron was suggested, but the idea was laughed at, because everybody knew that iron would not float. Richard Trevithick, an Englishman, planned an iron ship, however, and built it at Glasgow in 1818, calling it the *Vulcan*. It was in service sixty years, proving the value of iron ships. It was actually lighter in proportion to its carrying capacity than a wooden ship of the same size. After 1835 the position of the iron ship was assured. In 1859 the first iron steamboat was built and about 1870 steel (iron, page 314) took the place of wood in ships.

To understand why a steel ship floats one must know something about *specific gravity*. Here, *specific gravity is the ratio of the weight of a body to that of an equal volume of water* (Fig. 196).

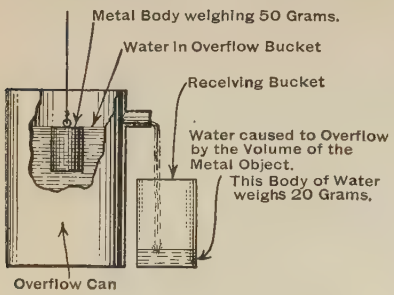

Metal Body weighing 50 Grams.
Water in Overflow Bucket
Receiving Bucket
Water caused to Overflow by the Volume of the Metal Object.
This Body of Water weighs 20 Grams.
Overflow Can

FIGURE 196. — SPECIFIC GRAVITY APPARATUS.

The metal weight pushes down with 50 grams pressure. The water pushes up with 20 grams pressure. The body sinks because it weighs $2\frac{1}{2}$ times as much as the water it displaces. Its specific gravity is 2.5. When will an object float?

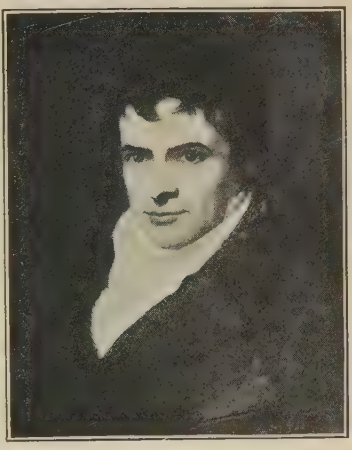
3. THE USE OF STEAM IN WATER TRANSPORTATION

315. The Steamboat.— The year 1807 was a most eventful one in the history of water transportation. In August the little *Clermont* steamed from New York to Albany, a distance of 150 miles, in 32 hours (Plate III). This was the more remarkable, because Fulton was told by engineers that water wheels could be moved by water but that they would never move a boat in the water. But Fulton figured that when the wheels turned, the pressure of the water upon them would cause the boat to move while the water would remain more or less stationary, because of its inertia. Can you explain this? The test showed him to be right. The *Clermont* was fitted with two side paddle wheels, each 15 feet in diameter, and when they turned, the boat moved, to the wonder of all and the discomfiture of his critics. Fulton's boat was also provided with a working beam. To-day the palatial (pȧ-lā′shăl) steamers of the Hudson River use the same type of walking beam with side wheels inclosed in paddle boxes.

316. Transatlantic Steamboats. — In 1838 the *Great Western* crossed the Atlantic in 12 days and $7\frac{1}{2}$ hours, using only steam for power. She made over 200 miles a day, consuming more than 450 tons of coal in crossing. In 1840 the

Robert Fulton (1765–1815)

Robert Fulton was a born experimenter. He was always playing with quicksilver and so won the name "Quicksilver Bob." He busied himself inventing toy machines, built paddlewheel boats, and experimented with guns. He was continually busy in finding out new facts and laws about his environment. He studied architecture and painting and while a young man became a portrait painter in Philadelphia. But his mind was ever on the subject of machines. In 1786 he went to England and saw Watt's steam engine at work. He recognized its possibilities in navigation and immediately began experiments along this line, working both in France and England but without encouragement from either country. His success was to be won at home.



Returning to New York in 1806 he formed a partnership with Robert Livingstone, a financier, and built a steamboat, the *Clermont*, named after Livingstone's estate on the Hudson River. On August 17, 1807, in the presence of skeptical and jeering crowds, the boat began its famous and successful journey to Albany. The day of the sailing vessel had ended and that of the steamship had begun.

No one can begin to estimate the value of Fulton's work to the world. The tremendous commerce of the oceans to-day is the result of his active mind and his scientific spirit. He is one of the world's great benefactors.

first steamboat to be used in regular passenger service began its trips between Liverpool and Boston. From that time to the present the problem of ocean travel has been to increase efficiency, safety, and comfort by increasing the size and speed and improving the shape of the hull.

317. The Screw-Propeller Boats. — Later, two and three propellers were used, and finally in 1908 the *Mauretania* and her ill-fated sister ship, the *Lusitania*, built with four propellers (two of which can be reversed by special gears) outdistanced all rivals, making the voyage across the Atlantic in 4 days, 20 hours, and 22 minutes.

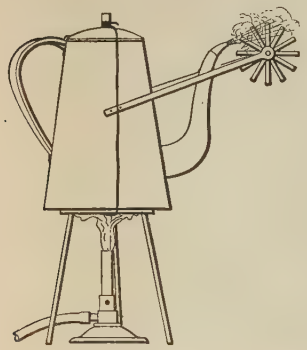


FIGURE 197. — A MODEL STEAM TURBINE.

318. The Steam Turbine. — The steam turbine has been a great factor in improving ocean travel. First used in 1897 in a ship called the *Turbine*, 34 knots an hour were made as against 24 knots in the old type of ship. The *Lusitania*, the best example of this type of ship, used turbines developing 68,000 horse power. This is the same as saying that it would take a line of horses 120 miles long, placed head to tail, to do as much work as that done by the engines of this mighty ship. Set up an apparatus as shown in Figure 197, start it going, and then explain the principle of the steam turbine.

319. Advantages and Disadvantages of the Steam Turbine. — The ordinary steam engines cause considerable vibration, but the turbines are practically vibrationless. They occupy less space, are more economical at high speeds, are easily controlled, and need few repairs. They are noiseless, steady, and powerful. On the other hand, they cannot be reversed. Two sets of turbines must be used, one for forward and one for backward speeds. But their advantages

far exceed their disadvantages and they seem to be assured of use for many years to come.

4. The Modern Steamship

320. The *Leviathan*. — This ship, a monster of the deep as its name implies, is now, with one possible exception, the largest ship afloat (Fig. 198). Built by Germany, she was taken by the United States during the World War and refitted,

Figure 198. — The *Leviathan*.

The wonder ship. Compare the sailboat to the great ship. A trolley car could go through its smoke stacks. What makes it float? How much water will it displace? Explain.

and is now in passenger service in control of the Shipping Board. Some idea of the tremendous size and capacity for carrying passengers can be gained from the table on page 374. "In elegance and sheer beauty this ship excels anything the world has ever seen." Equipped with social halls, palm courts, restaurants, and enormous dining hall, Pompeiian bathing pool holding 120 tons of sea water, and steam, Turkish, and electric baths, it is more than a floating hotel and palace.

There are ten million wires in the ship to control her electrically; it costs nearly $100,000 for the food alone to supply her passengers for one voyage and it cost over $8,000,000 to put the ship in condition for use. Now compare this with the galleon of Columbus, the *Mayflower*, or even the ocean liners of twenty-five years ago, and one can get some idea of the enormous advances that have been made in ocean travel.

LEVIATHAN FACTS

Length	950 ft.
Width	100 ft.
Height, keel to bridge	124 ft.
Height, keel to stacks	180 ft.
Draft	40 ft.
Tonnage, gross	59,957 tons
Horse power	100,000
Boilers	46 boilers, 30 furnaces
Decks	9, of steel; area 7½ acres
Capacity	973 1st class passengers
Capacity	548 2d class passengers
Capacity	944 3d class passengers
Capacity	1334 4th class passengers
Crew	1700
Total capacity	5499

— From the *Boston Globe*.

5. The Principle of the Submarine

321. Submarines. — The principle upon which the submersible boat works was discovered by Archimedes, but it was never put to practical use until 1775, when the first submarine was built by David Bushnell of Westbrook, Maine. In fact, the destructiveness of this type of boat was never fully demonstrated until the World War.

The modern submarine was developed by John Holland, an American inventor. His first boat was 60 feet long, weighed 75 tons, and carried 10 tons of water as ballast. Horizontal rudders along its sides gave it great stability. It could sink 30 feet in 10 seconds. The latest boats are nearly 200 feet long, carry 35 to 40 men, have a wide cruising range, and are extremely complex in construction (Fig. 199).

322. The Principle of the Submarine. — A submarine is so built that its total weight is a trifle less than the weight of an equal volume of water. It will thus just float. By adding water to its tanks, its weight is increased and it sinks. Explain. As its weight is lessened by pumping out the water ballast, it rises. Pressure gauges indicate to the commander the depth of the boat's position at any moment.

FIGURE 199. — A SUBMARINE CRUISING AS A SURFACE BOAT
Why does it float? When will it sink? When will it rise?

6. How Water Travel Is Made Safe

323. The Navigation of Ships. — Certain maps are made to show steamship routes all over the world. How do ship captains know in what direction they are going, whether they are following the official route, and where they are at any particular time?

324. The Compass. — The compass is useful because of the peculiar properties of its steel "magnetic needle." This assumes a definite relation to the magnetic poles of the earth, if allowed to move freely. A modern mariner's compass is very complex, the dial being divided into 32 segments and is set so as always to occupy a horizontal position on board ship. Explain.

325. The Chronometer (krŏ-nŏm′ē-tēr). — This is a clock which keeps accurate Greenwich time. By noting the time

on the clock and the time the sun passes the noon meridian each day, the exact longitude of the ship can be located, as each hour means 15°. Thus if it is 3 P.M. Greenwich time when the sun passes the meridian, the ship must be exactly 45° west of Greenwich meridian or longitude 45° west. Do you see this? Explain it.

326. Method of Determining Latitude. — The method of determining latitude when out of sight of land is a complicated process, requiring a specially trained officer for its accomplishment. We can, however, get a general idea of the process. Each day the navigating officer, using a *sextant* and certain tables which are printed in the *Nautical Almanac*, measures the angle formed by lines running from his position to the sun and to a point on the horizon directly under the sun. From the size of this angle he can determine his latitude.

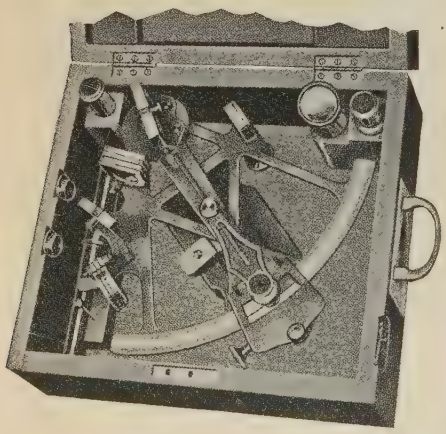


FIGURE 200. — A SEXTANT INCLOSED IN ITS CASE.

Clouds, the season, and other factors affect the calculations, but the general method is always the same except when skies are overcast. Then the sailor must pick his course by "dead reckoning," which means taking into account his last known position and estimating his present position by allowing for such factors as the boat's speed, cross-winds, and favoring or opposing currents.

327. Method of Determining Speed. — In the early days the rate of speed was determined by dropping overboard a block of wood attached to a rope and allowing it to be paid

out. Knots tied in this rope at regular intervals were counted as they passed overboard. The rate of speed was then determined by the number of knots which passed over in a given time. Thus the word "knot" came to be used. The modern log is an instrument with revolving vanes which is dragged through the water and which registers the speed on a dial much as a speedometer works on an automobile. (Fig. 201.) The apparatus for measuring the distance covered is also called the log, but it is attached to the vessel's propeller shaft and the revolutions are registered in miles.

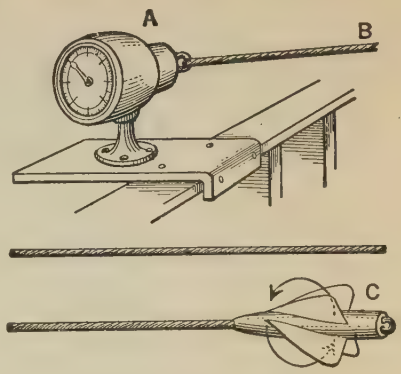


FIGURE 201. — THE SHIP'S LOG.

Note the speedometer **A**. The cord **B** connects with the propeller **C**. Why does it revolve? How fast does it revolve?

328. Safety of Travel. —The ocean is the common highway of the world. It is free to every one, but this freedom leads to disaster unless extreme precautions are taken to avoid dangers in the shape of reefs, rocks, icebergs, collisions with other vessels, sunken ships, and floating derelicts.

The great ocean liners, for these reasons, follow well-defined ocean lanes or paths, all vessels going in one direction following one lane and all going in the opposite direction following another lane. To avoid icebergs, the paths between the United States and Europe are moved southward during the winter and spring.

Again, all ships constantly use accurate charts upon which are shown all islands, shoals, reefs, rocks, sunken ships, and other obstacles. These charts when used with the Nautical Almanac, the compass, the sextant, and the log make ocean travel comparatively safe to-day.

Recently improved appliances for protection include the microphone (mī′krō-fōn) for detecting the sounds of bells situated under water on reefs and rocks, and certain harbors are now equipped with live electric cables set at the deepest part of the channel. All incoming ships follow this cable, following it by the use of wireless vacuum tube detectors, which are sensitive to electric vibrations. The wireless

U. S. Bureau of Lighthouses.

FIGURE 202A. — A GOVERNMENT LIGHTHOUSE AT HOG ISLAND, R. I.

Our harbors and shores are well dotted with these life preservers — lights that warn sea captains of dangerous rocks and shoals. Explain how this lighthouse is adapted for its quiet work.

telegraph and telephone also keep ships in constant communication with the shore and with each other so that when trouble occurs the S. O. S. call brings at once ships from every direction to the rescue.

Finally, lighthouses placed upon high promontories or reefs and provided with high-powered revolving lights give a steady or intermittent glow and warn of dangers (Fig. 202a). In harbors, highly colored buoys fitted with sirens and bells

warn of hidden rocks, while in deep waters lightships and buoys guide ships past danger points and through narrow channels (Fig. 202b).

329. Water Travel and the Work of the World. — Water commerce is absolutely essential to prosperity and the carrying on of the work of the world. Cut off the Great Lakes, and Chicago, Detroit, Cleveland, and Buffalo would be

U. S. Bureau of Lighthouses.

FIGURE 202B. — DIAMOND SHOAL LIGHTSHIP OFF COAST OF NORTH CAROLINA.
Where sand bars and shoals shift a lighthouse would be worthless. Why? These lightships throw their lights at night and warn of hidden dangers.

isolated. Block up the Hudson River, and New York and Albany would suffer greatly. Stop ocean traffic, and the whole world would feel it. The development of the steamship has created a new world. Distances have been eliminated. The whole world is close to every one of us. All countries are neighbors. Superstitions, old ideas, and seclusion of peoples are giving way to progress, cöoperation, interdependence, and world-wide sympathy.

REVIEW OUTLINE

1. Water Transportation: Early methods; relation to discovery of new lands. Early ships: oaken galleys; sailing ships. Importance of invention of the compass.
2. Buoyancy and Water Travel: Need of buoyancy in ships. Discovery of Archimedes. Meaning of buoyancy. Practical use in ship building.
3. Stability: Definition. How secured in ships.
4. Sailboats: Principles involved in sailing a boat. Disadvantages of early sailing vessels; advantage of the schooner.
5. Iron Ships: The first iron ship. Meaning and importance of specific gravity as applied to ships. Why iron ships float.
6. Steamboats: Fulton and the *Clermont*. Principles involved.
7. Transatlantic Steamships: The *Great Western* (1838). The screw propeller ship. The *Mauretania* (1908).
8. Marine Engines: The steam turbine (1897); how it works. The *Lusitania*. Advantages and disadvantages of the steam turbine.
9. The Modern Steamship: Features of the *Leviathan*.
10. Submarines: The work of David Bushnell and John Holland. The principle of the submarine.
11. The Navigation of Ships: The importance and principle of the compass. The chronometer and its use. The sextant. Determination of speed by the knot. The log.
12. Making Ocean Travel Safe by: (1) Charts; (2) ship lanes; (3) microphones; (4) electric cables; (5) wireless telegraph and telephone; (6) lightships, lighthouses, and buoys.
13. How the steamboat and steamship have caused world progress.

SUMMARY

The early daring of a few men made *commerce* with near-by countries profitable. This resulted in attempts to improve methods of water travel.

The early *sailboat* of the Egyptians was a very crude affair. The Phœnicians built strong ships of oak and manned them with galley slaves and finally, sails. But even these ships were slow, because of their inability to go fast into the wind even by the aid of oars. In sailing, these boats had to go with the wind or not at all.

With the invention of the *compass*, real ocean travel became possible. Men knew then where they were going and how to get back again. With Archimedes' principle in mind, ships were built large

enough to combat the ocean waves and carry more cargo, but it was not until the nineteenth century that boat builders would believe that iron ships could float.

Stability is an important factor in boat design. It may be secured by use of (1) a *wide beam;* (2) *air chambers;* (3) *fixed ballast;* (4) *weighting the keel;* or (5) *a centerboard.* An improvement in the modern sailboat is the better shaping of the hull and the use of the weighted keel or centerboard to allow it to " tack " and to prevent its capsizing or " drifting."

As ocean ships became larger, their stability was increased by their enlarged bulk below the water line, their greater weight, and larger cargo capacity. In *iron ships*, for the first time, the laws of *specific gravity* were applied to ship-building materials which were heavier than water. The hollow hull kept the weight of the volume of water displaced equal to the weight of the iron ship, and it floated. Since 1870 most ships are made of steel.

The triumph of *Robert Fulton* in 1807 was the real forerunner of the modern ocean liner. In the *Clermont*, to-and-fro motion was made rotary by the use of the working beam and paddle wheel. This was followed by the *screw propeller*, *steam turbines*, *high pressure engines*, and *improved hull construction.* The great *Leviathan* includes all of these ship improvements.

The *submarine* was invented and improved until it has become an efficient engine of destruction, simple in principle but very complex in structure.

Of tremendous importance is the safe navigation of ships because of their great cost and their large cargo of people and freight. The *compass*, *sextant*, *chronometer*, *modern log*, etc., have been invented and improved to increase safety of ocean travel. Furthermore, improved *charts* showing danger spots, the laying out of *ship lanes*, the use of *lightships* and *lighthouses*, the *microphone*, the *electric cable*, the *wireless telephone* and *telegraph* have all been of great aid in making travel on the sea as safe as travel on the land.

Remember that:

1. The invention of the compass made modern water journeys possible.
2. The invention of the steam engine made rapid ocean travel possible.
3. Buoyancy and stability are the two great requirements in the construction of all ships.
4. Steel ships are buoyant because they are built to displace an enormous amount of water.

5. The improvement in the instruments of navigation and communication has made water travel as safe as that on land.

THOUGHT QUESTIONS

1. Under what conditions will an object float in water? When will an object sink?
2. How is the manner of loading a boat with freight important from the standpoint of stability?
3. Some countries require ship owners to have painted on the bows of their ships a foot rule indicating the point of the water line when the ship is loaded to full capacity. What is the idea of this?
4. Why do racing yachts have a very deep keel?
5. Why cannot a submarine sink to a depth greater than about 250 feet?
6. Why must a submarine always use two types of engines for propulsion?
7. Why cannot the exact reading of the compass be accepted?
8. Explain the use of the log and the sextant.
9. What are the chief advantages of the Panama Canal to the United States? to the world?

SPECIAL PROBLEMS

1. Visit a ship yard and observe several types of boats under construction. Study a sailboat or yacht and observe its lines. Is it made for cargo? Does it appear that it will displace much water? Would this be desirable in a sailboat? What structure prevents the boat from tipping over under sail? What does this take the place of? Note the width of the hull. Account for this.

Next observe a steamer or freight vessel. Note the bigness of hull and its great depth. Account for this. Of what is the hull made? How do you explain that this boat will float when launched? Observe the steering apparatus or rudder. Explain how turning this rudder to the left will turn the boat to the left, while turning it to the right will turn the boat to the right. Note the propellers. Why are they placed where you see them? Account for the curves in the blades. Note how small these propellers are in proportion to the size of the ship. Why is the bow so pointed? If possible, study the interior of the ship, especially the engines. Find out the type of engine used, its connection with the propellers, its horse power, its number of revolutions per minute and the speed of the ship in knots and in miles. Report on your visit to the class.

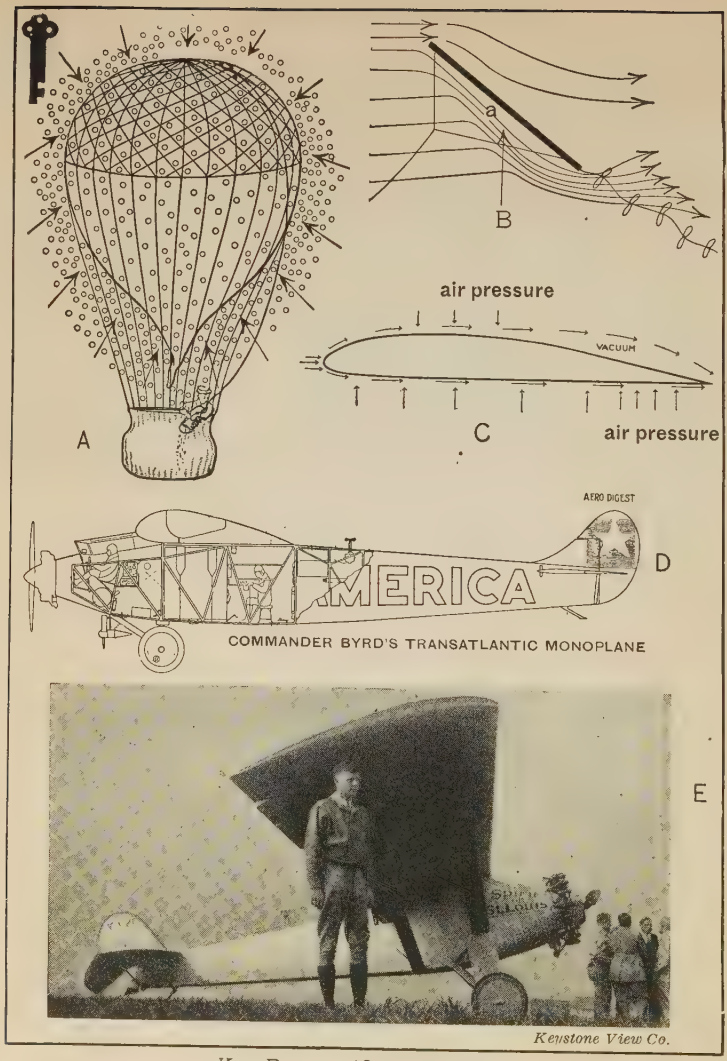
2. With the knowledge gained in your visit to the ship yard,

make a toy sailboat, rig it and sail it. Write up your experiences while making the boat, telling of your difficulties and the way you overcame them. Explain the principle of the sailboat. Explain its buoyancy and tell why it floats.

3. Learn to row a boat and become expert in handling it in all conditions (backing, turning, handling of oars so as to get most power, rowing in rough water, etc.). Report your experiences to the class.

4. Learn to sail a sailboat. Explain its principle to the class. Learn to tack, steer and handle the sails. Explain to the class the principle of tacking, steering, the use of the centerboard and explain the difficulties to be overcome in becoming a good sailor.

5. Learn to run a motor boat. Explain to the class the principle of the engine, its care, starting, stopping and control of its speed. Explain the lines of the boat and their purpose and advantages. Tell the class the difficulties to be overcome in running a motor boat.



KEY PICTURE 12c. — AVIATION.

A. What makes the balloon rise? **B.** What holds the kite up? **C.** A cross-section of the wing surface of the *Spirit of St. Louis*, drawn to scale from a blueprint submitted by the manufacturers of the plane, the Ryan Aircraft Manufacturing Company. The arrows show how the air is made to support the plane in flight (Section 335). **D.** The *America*. **E.** Charles A. Lindbergh.

C. TRAVEL IN THE AIR

Brutes find out where their talents lie;
A bear will not attempt to fly;
A foundered horse will oft debate
Before he tries a five-barred gate;
A dog by instinct turns aside
Who sees the ditch too deep and wide;
But man we find the only creature,
Who, led by reason, combats nature;
Who when she loudly cries — forbear,
He, led by science, takes the air.

— *Swift.*

Did You Ever Fly a Kite?

Flying a kite looks easy. Can you explain why it stays up there in the sky? Can it be that the air has anything to do with it? Did you ever see a balloon, either large or small, rise? Well, why did it go up? Did you see the ZR3 come to the United States? How beautiful she looked in the sky! How could that giant carry 40 men so high in the air and for such a distance? Airplanes are so common now that people do not stop to see one pass. But can you explain why it stays in the air? Here is another fine test of your ability to explain things. If you find it too hard to tell about these things, this chapter will help you.

Some Practical Questions :

1. Why does a stone fall rapidly to the ground while a piece of paper flutters slowly to the ground?
2. Why does a large piece of paper fall to the ground faster than a small piece of paper of the same kind?
3. Why will a piece of cotton soaked in oil and lighted and then placed beneath a paper balloon cause the balloon to rise in the air?
4. Why will a paper glider rise in the air if given a thrust?
5. Why will a kite rise in the air on a string when pulled against the wind, but fall if the string becomes slack?

Home Problem. — Make several types of gliders out of cardboard or paper. Try them out and decide which flies the best

(swiftest, and stays in the air the longest). Determine the causes for this.

Field Problem. — Visit, if possible, an airplane factory. Observe a machine under construction and determine its principal parts and their functions. Learn as many things about the machine as you can from the mechanic and report your findings to the class.

1. Balloons

330. The Dirigible Balloon Finally Perfected. — In 1872 Dupuy de Lome built a real dirigible balloon, driven by propellers three feet in diameter. It carried 14 passengers

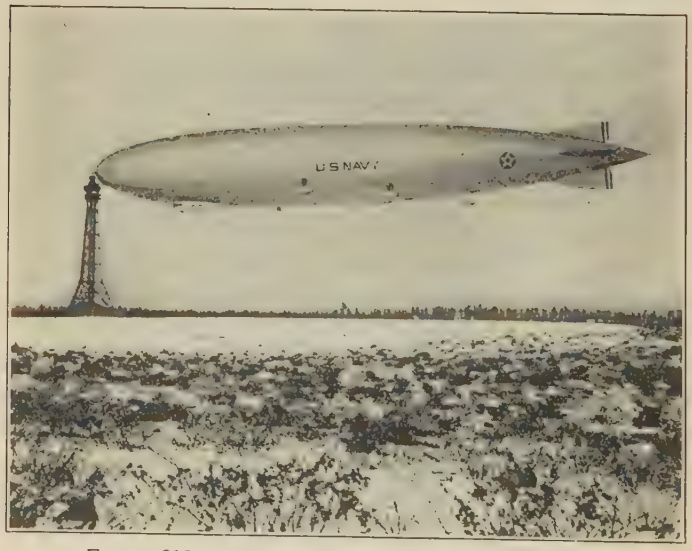


Figure 203. — The *Los Angeles* at Lakehurst, N. J.

What is the use of the mast? Why does this dirigible float in the air? How is it controlled in flight? How propelled? How long do you think this airship is?

and made a speed of 7 miles per hour. Soon following these experiments, Hiram Maxim and Professor Langley, with Count Zeppelin, undertook the construction of a monster "airship," 416 feet long, 38 feet in diameter, divided into 17

air-tight compartments, and propelled by four screw propellers. In July, 1901, Count Zeppelin and four assistants started on a journey, attaining a speed of 18 miles an hour; the ship responded perfectly to the rudder (Plate III).

331. Recent Progress. — The dangers connected with the lighter-than-air ship seem almost unsurmountable. The Z38, a regular army British ship, buckled while in flight in 1921 and fell into a river, and all her crew, including some American officers, were drowned. Next, the *Roma*, a monster ship, collapsed while in a trial flight near Washington, caught fire and 34 of her crew were killed. The dangers of all gases except helium make the dirigible ship a death trap. Their future use will depend upon marked improvements in construction and handling. The transatlantic flight of the monster ZR3, a German-made ship now known as the *Los Angeles*, showed the possibilities of a giant lighter-than-air ship (Fig. 203). The flight of Roald Amundsen in the *Norge* across the North Pole in May, 1926, suggests future uses of these giant airships. The tragic loss of the *Shenandoah* showed that these large ships must be structurally sound to withstand a severe storm.

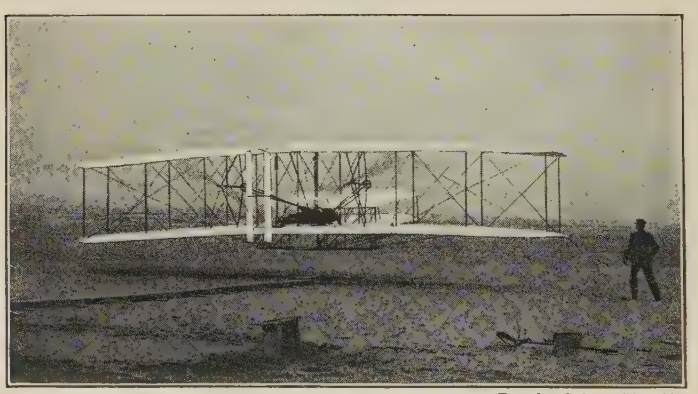
2. The Langley Airplane

332. Air Resists Moving Objects. — You have seen how moving air is used in sailing a boat. The air here actually does work, but sometimes, through its inertia, it hinders travel. It seriously checks the speed of an automobile. Can this resistance of the air be used to our advantage?

333. Experiments in America. — Birds are, on the average, 1000 times heavier than the volume of air which their bodies displace; yet they fly. Why could not man also, though so much heavier than air, hope to find some way to fly? Hiram Maxim, the inventor of the machine gun, and Professor Langley, of the Smithsonian Institution in Washington, D. C., both worked on the principle that air has inertia and will

support a weight for a fraction of a second. They constructed a model machine with two wings, equipped with a propeller revolving 1200 times a minute. The trial test was a great success, the machine flying in a circle 100 yards in diameter over the water and alighting in perfect condition.

Three problems were solved by these tests. (1) A flying machine could lift itself from the ground; (2) it would lift more than a balloon of equal weight; (3) it could be sent through the air at a high rate of speed. Balancing and stability had still to be solved.

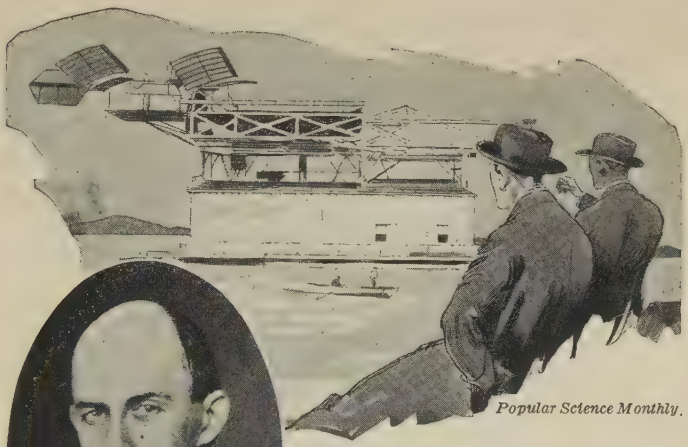


Popular Science Monthly.

FIGURE 204. — THE FIRST FLIGHT EVER MADE BY A HEAVIER-THAN-AIR MACHINE CARRYING A PASSENGER.

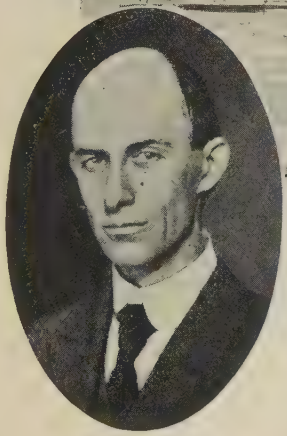
Tell why this machine flew.

334. The Wright Brothers. — Using Langley's results. Wilbur and Orville Wright flew kites for months in order to find out how and why they stayed in the air. The brothers then built small gliders and tested them. Finally, they built gliders having surfaces of 200 square feet and large enough to carry a person. With an 18-mile wind blowing these gliders would just keep in the air, where they were studied hours at a time, one man on the ground and the other in the glider. The Wrights, having solved the problem of remaining in the



Popular Science Monthly.

Orville and Wilbur Wright



Wilbur Wright

On September 12, 1908, at Fort Meyer, Va., Mr. Orville Wright made the first practical airplane flight. This victory in the air electrified the world. The result, however, was not one of chance. It was a triumph of patient work and a success preceded by discouraging failures. The two Wright brothers never gave up. They paid a price of great labor and to-day we reap the reward of their work.

Orville and Wilbur Wright were the proprietors of a small bicycle repair shop in Dayton, Ohio. They were mechanics. They read everything they could find on the subject of gliding. They flew kites, watched birds fly, and experimented with gliders in their attempt to solve the problem of flying.

For three years they worked, and in December, 1903, they flew for 59 seconds in a biplane driven by a 12 h.p. gasoline engine. In 1909 a satisfactory endurance test was made before government officials accompanied by President Roosevelt.

Wilbur Wright died in 1912 knowing full well the great value of the invention developed by him and his brother. Beginning as humble mechanics, these brothers became scientists of the finest type. Free from boasting, quiet, unassuming, and deeply religious, these two men are entirely worthy of their fame. Their names rightly belong to the list of great Americans.

air, next solved the problem of control by tilting the wings of the glider. By 1901 they could sail 900 feet down hill against the wind. The last problem was to propel this glider. On December 17, 1903, they put a gasoline motor in the glider and flew for some minutes — the first time in history that a heavier-than-air machine had lifted itself off the ground with a passenger (Fig. 204).

With a simple kite you can solve for yourself some of the problems which faced the Wright brothers.

3. How the Airplane Stays in the Air

335. Why the Airplane Stays in the Air. — When a boy starts to fly a kite, he runs against the wind with it, holding it with a string attached to it in such a way that its surface

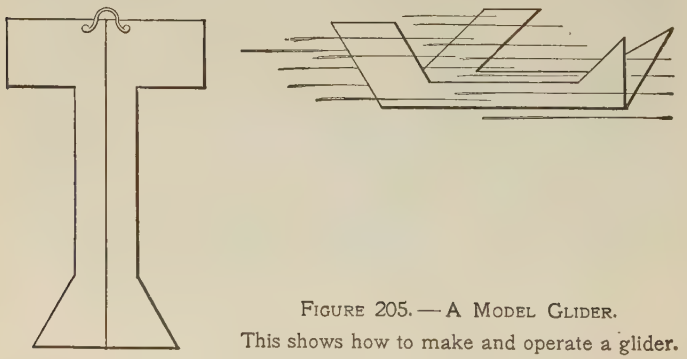
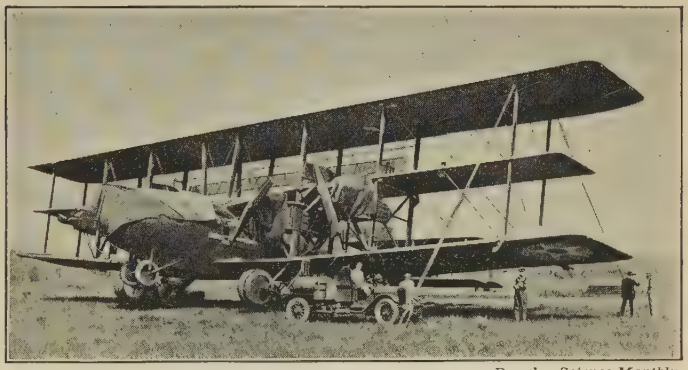


Figure 205. — A Model Glider.
This shows how to make and operate a glider.

is held in an inclined position with reference to the wind's direction. But when the kite rises high enough to feel the wind, it keeps up in the air even though the boy stands still. If the boy now runs or pays out the string, the kite rises higher, really sliding up on the air, because the air is moving against the kite. Remembering that the kite is many times heavier than the volume of air it displaces, how does it stay up in the air? This can be partly discovered by an experiment. Make a glider as shown in Figure 205 and try to find out by using it how it stays in the air.

But you have not entirely explained why the airplane stays in the air. The inertia of the air and the revolving propellers are not sufficient to keep the plane up. This the Wright brothers soon discovered. What other force can possibly help the airplane to fly? This you can easily find out for yourself.



Popular Science Monthly.

FIGURE 206A. — A BARLING BOMBER.

Note the three planes (*triplane*). Compare the airplane and the automobile as to sizes. What is the advantage of the extra plane? What is the special work of this airplane?

Suggested Experiment. — Take an ordinary sheet of paper (8″ × 11″) and holding it by one edge in front of the mouth, blow the breath across its upper surface. What happens? Explain this result. Do you think the atmospheric pressure is less above than below the paper? What did your breath have to do with this? Why did the paper rise?

If the airplane wing is *cambered* (arched toward the middle) what effect will this have on the air above and behind the planes? Study Key Picture 12c. What helps keep an airplane in the air?

4. THE WRIGHT AIRPLANE

336. The Wright Biplane. — The lifting power of this machine was obtained by two horizontal planes of canvas

stretched over wooden frames. It was kept on an even keel by the warping of the wings or planes by means of levers, a vitally important feature of the whole mechanism. The connecting of the vertical rudders with the mechanism for warping the planes on the same lever so that they could be worked together by one movement of the lever was patented in 1906 and the whole world then knew the combination. The rapidity of the advancement of aviation since 1918 is well shown in the accompanying news item.

MAUGHAN CROSSES THE UNITED STATES BETWEEN DAYLIGHT AND DARKNESS

June 24, 1924. Yesterday Lieut. Russel L. Maughan crossed the United States in a government plane, starting at 3:59½ A.M. daylight-saving time and reaching San Francisco at 9:47 Pacific time. He made five stops for fueling and he accomplished a feat which in his own words was not remarkable, but "that can be done every day in the week." This trip but proves the possibility of mobilizing the entire airplane forces of the United States at any one spot in it, in one day. — *New York Times*, June 29, 1925.

Special Problem. — Let some member of the class volunteer to write the Office of the Chief of Air Service, War Department, Washington, D. C., asking for data concerning the very latest records made in aviation, including information concerning distances covered, speed, altitude, and lifting power.

Study Figures 206a and 206b. Tell how the planes shown differ from the original Wright plane and to what uses they are put. How are they adapted to the work they do?

337. The Airplane and the Work of the World. — The future of the airplane will be concerned mostly with constructive rather than with destructive work. The Washington Conference attempted to limit its use in warfare and future conferences will without doubt place it where its terrible, destructive power will not be called into action. In the works of peace, its future is assured. Used now all over

the world in carrying mail, its schedule scarcely ever varies. It carries freight of all kinds and scores of passengers daily. It is now used in police work, in forest ranger work, in superintending large ranches in the West, and even to spray trees and crops, especially cotton. The flight of Commander

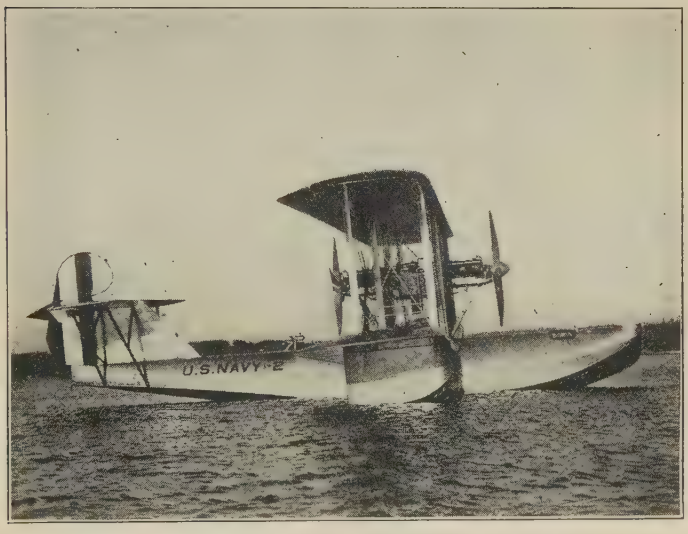


FIGURE 206B. — A NAVY SEAPLANE.

This plane (a *biplane*) has two engines of 700 h.p. each. Contrast this type of plane with that of the Barling bomber. What is the advantage of this type? Which, do you think, is the easier to operate? Why?

Byrd to the North Pole and back in 15 hours in May, 1926, was a wonderful achievement for the heavier-than-air machine. The time is not far off when the airplane will be as cheap and as common as the automobile.

REVIEW OUTLINE

1. The Dirigible Balloon: Advantages. De Lome (1872). Experiments of Zeppelin, Maxim, and Langley (1901). The transatlantic flight of the ZR3 (*Los Angeles*) (1924); its importance.
2. Heavier-than-Air Machines: Work of American experimenters (Maxim and Langley).

3. The Wright Brothers: Early experiments. Methods of work. Steps in the solution of the problem of flying in 1901, 1903, and 1908.
4. How the Airplane Stays in the Air: By (1) shape of planes; (2) resistance of the air due to its inertia; (3) speed of the plane; (4) control of the plane; etc.
5. The Wright Biplane: Special features. Lifting power gained by use of: (1) wings and (2) engine. Controlled by: (1) vertical rudders; (2) warping of wings.
6. Recent types: The airboat (hydroplane).
7. Present and Future Uses of the Airplane.

SUMMARY

In 1872 de Lome, and in 1901 Langley, Maxim, and Zeppelin developed real *dirigible balloons*. These were followed by the great Zeppelin airships. A great step in the perfection of these ships was the construction and flight of the ZR3 (now the *Los Angeles*) from Germany across the Atlantic to the United States in October, 1924.

Meanwhile, the American heavier-than-air experimenters, *Langley* and *Maxim*, discovered, about 1900, some fundamental laws of flight. These the *Wright brothers* used in constructing the first real airplane. From 1903, the year of the first real flight, to 1908, all the essential problems of real flying were solved. It was then definitely known how an airplane goes up into the air and why it stays in the air. Since 1900, distance, speed, altitude, and lifting power records have been repeatedly broken. The emphasis is now being placed upon *increased safety* and *comfort* for the pilot and his passengers.

The real test of the airplane came during the World War. The after-war development has brought about a much greater carrying capacity of the airplane, and greater comfort and safety in the dirigible balloon. It is almost certain that future travel will be more and more by airplane because of its cleanliness, speed, and safety.

Remember that:

1. Air offers resistance to all objects.
2. The broader an object is the greater will be the air resistance to it.
3. All balloons are lighter than the air which they displace.
4. All airplanes are heavier than the air they displace.
5. The great discovery of the Wright brothers was how to propel and control a heavier-than-air machine.

Official, U. S. Army Air Service.

Wide World.

FIGURE 207. — PLANES IN ACTION.

Above: The Round-the-World Flyers approaching New York City, September 8, 1924. Why was this trip a notable one?

Below: A giant Fokker *monoplane*, with an Avro biplane disporting above it.

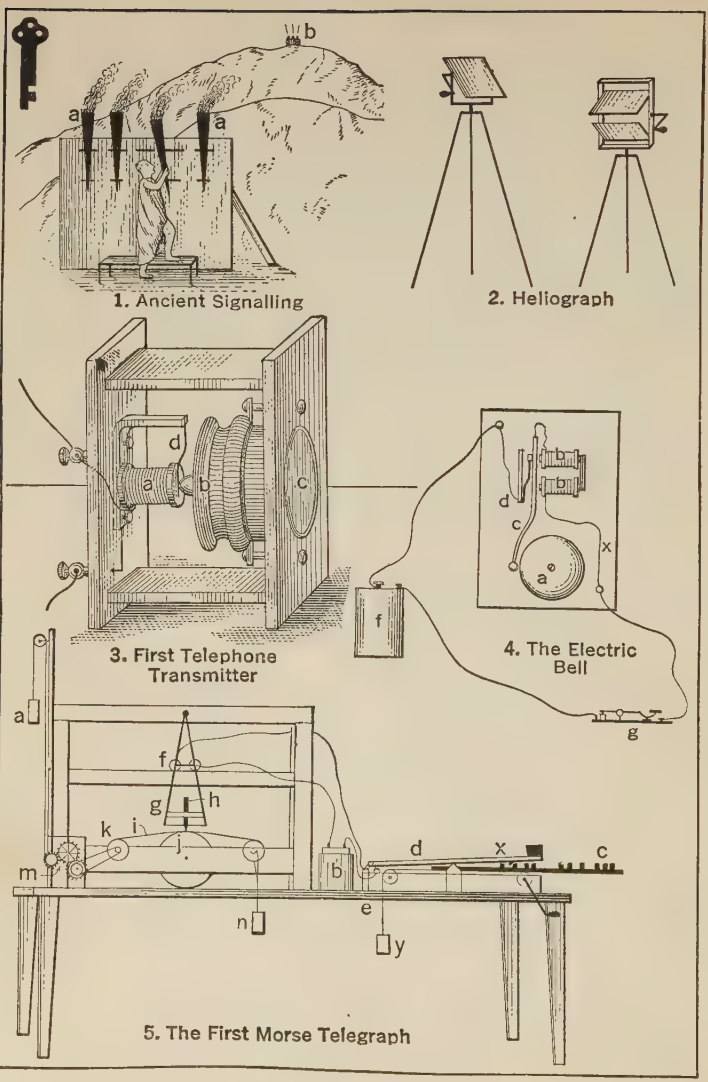
THOUGHT QUESTIONS

1. How is it possible to keep a balloon at a given altitude since there is always a slight leakage of gas from it?
2. What is the disadvantage of the use of hydrogen in balloons?
3. Why will the speed of a balloon upward diminish as it rises?
4. What is the advantage of a dirigible over an ordinary balloon?
5. Why is it not probable that we shall ever fly with moving or flapping wings attached to the body?
6. What great principle did the Wright brothers discover and use that made aviation successful?
7. What form must the wings of an airplane assume to get the most lifting power out of the air?
8. How was equilibrium maintained in the early Wright plane? in a Curtis plane?
9. Could one fly to the moon in an airplane? Explain.
10. How must contestants for altitude records equip themselves before going up?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Bachmann. Great Inventors and Their Inventions. American Book Co.
Chamberlain. How We Travel. The Macmillan Co.
Chatterton. Marvels of the Ship. J. B. Lippincott Co.
Collins. How to Fly. D. Appleton and Co.
Collins. The Boy's Airplane Book. F. A. Stokes Co.
Collins and Collins. Boys' Book of Submarines. F. A. Stokes Co.
Cressy. Discoveries and Inventions of the Twentieth Century. E. P. Dutton and Co.
Crump. The Boy's Book of Railroads. Dodd, Mead and Co.
Darling. All About Ships. Funk and Wagnalls Co.
Darrow. Boy's Own Book of Great Inventions. Harcourt, Brace and Co.
Darrow. Masters of Science and Invention. Harcourt, Brace and Co.
Decker. The Story of the Engine. Charles Scribner's Sons.
Hall. Wonders of Transportation. Dodge Publishing Co.
Holland. Historic Inventions. Jacobs and Co.
Johnson. Modern Inventions. F. A. Stokes and Co.
Miller. Canoeing, Sailing and Motor Boats. Doran.
Molter. Knights of the Air. D. Appleton and Co.

Page. Motor Boats and Boat Motors. Henley Publishing Co., New York City.
Putnam. Lighthouses and Lightships of the United States. Houghton Mifflin Co.
Warman. The Story of the Railroad. D. Appleton and Co.
Whyatt. Streets, Roads and Pavements. Isaac Pitman and Sons.
Williams. The Wonders of Science in Modern Life. Vol. 3. Funk and Wagnalls Co.
Williams. How It Works. T. Nelson.



KEY PICTURE 13. — SOME METHODS OF COMMUNICATION.

Identify the lettered parts in **1**, **3**, and **4**. Compare **3** and **4**. In **5**, **a**, **i**, **j**, **k**, **m**, **n** rotate a paper strip under the pencil **h**; **fg** is an electromagnet; **b** is a battery; and **c**, **d**, **e**, **x**, **y** transmit impulses to **fg**.

CHAPTER XIII

THE USE OF ELECTRICITY IN COMMUNICATION

They may not pause when the sun is high,
Nor rest when the light is low;
For while men live, and act and die,
The word flies to and fro.
It leaps the sea, it spans the plain;
On throbbing wire and mighty chain,
It runs like fire from main to main,
That the world may see and know.

— *The Argosy.*

Of Course, You Have Talked on the Telephone!

This is easy, but think of the people who lived 100 years ago who wanted to talk from Philadelphia to Boston. What did they do? Have you ever heard of the electromagnet? Well, it is found in every telephone and telegraph! It is found even in your doorbell! You have heard the telegraph sounder clicking in the railway station. What makes it tap in this manner? What do you know about the wireless telegraph and the radio? You have heard concerts over the radio. Have you wondered how this is possible? Do you really hear the band play in your loud speaker? Have you ever thought how important the telephone, the telegraph, and the wireless are to the life of to-day? Think this over as you study this chapter.

Some Practical Questions:

1. Why did early peoples know little of each other?
2. Account for the fact that the battle of New Orleans in the War of 1812 was fought after the treaty of peace was signed.
3. Why are wires used in connection with telegraphs and telephones?
4. When you talk with a person over the telephone do you actually hear that person's voice?
5. In radio what takes the place of the wire used in the telephone?

Home Problem. — List all the means of communication used in your home. Give the structures used to carry on this communication.

Field Problem. — Make a list of all the means by which information is carried from one person to another in your community. Explain the principle of the apparatus used in each case.

1. The Electromagnet and Your Doorbell

338. Communication and the Work of the World. — Modern transportation was made possible only through the development of communication between distant points. Prior to 1860 business moved at a very slow pace in this country. By the invention of the telegraph, transportation could be controlled, accidents reduced, and orders sent in a few moments which before had taken days and even weeks to deliver. In the earlier period a merchant in New York City was obliged to order oranges from Florida by mail or personal messenger. He might get his oranges in two or three weeks. To-day the order can be radiophoned in a few seconds and a carload of fruit can be delivered within forty-eight hours of the time it is ordered. Furthermore, we are able to know the news of the whole world very soon after the occurrence of the events which the news describes. Study Plate III and give the important steps in the development of communication.

339. The Electromagnet. — Just sending a current through a wire will not ring a doorbell unless the bell is so constructed as to use this current in a way that will cause the clapper of the bell to vibrate very rapidly against the

gong of the bell. How is the bell built to do this? A study of the electromagnet will tell the secret.

2. The Principle of the Electromagnet

Demonstration 36 : *Problem: How can one make and work an electromagnet?*

Materials: A heavy iron nail or iron rod about six inches long; eight feet of insulated copper wire; a push button; a wooden support for the nail or rod; and a battery of dry cells (Fig. 208).

Method: A. Wind the wire about the nail or rod in close smooth turns, leaving the ends free. Connect one end to one binding post of a dry cell battery, the other to a binding post of the push button.

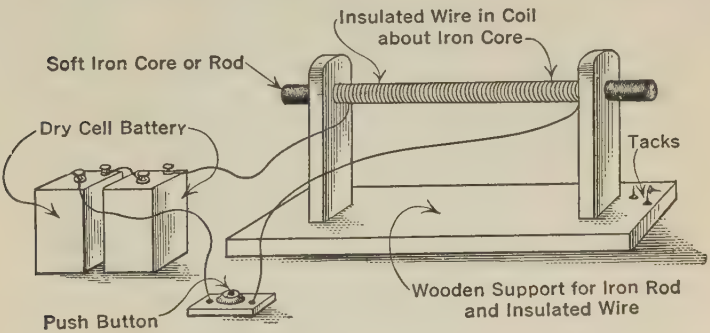

Insulated Wire in Coil about Iron Core
Soft Iron Core or Rod
Dry Cell Battery
Tacks
Wooden Support for Iron Rod and Insulated Wire
Push Button

Figure 208. — An Electromagnet.

What are the uses of each part?

Join the other binding post of the push button and the dry cell battery by a second short piece of wire. Be sure that these connections are all tightly made.

Now close the electrical circuit with the push button and place a tack on the end of the nail or rod. Break the circuit.

B. Attach the second battery in the circuit. Hold the tack near the end of the rod. Try other substances such as nails, a jack-knife, small tools. Do they hang to the rod? Now close the circuit again. Try each substance again. Break the circuit.

C. With the two batteries attached remove half the turns of wire from the rod, cut off the extra wire and connect again. Try to pick up the same substances again. Note the results. Explain them.

Observations: What happens when the circuit is closed? When it is broken? When is the rod a magnet? What makes it a magnet? How long does it remain a magnet? This is a *temporary magnet.* Why is it called an electromagnet? Do you notice that the pull is stronger with two batteries than with one? What effect does the number of wire turns have on the strength of the magnet? How can a very strong electromagnet be made?

Conclusion: Explain how a good electromagnet can be made and just how it works. Study Key Picture 13 as an aid to your explanation.

Practical Application: Now study very carefully an electric bell and see if you can find any part of it which resembles the electromagnet you made. If you find such a part, connect the bell with a dry cell battery and see just how the part works. By turning the contact screw in and out determine the effect upon the ringing of the bell. Does the bell at any time fail to ring? Why? Trouble at home with your doorbell may be due to other causes besides a worn-out battery.

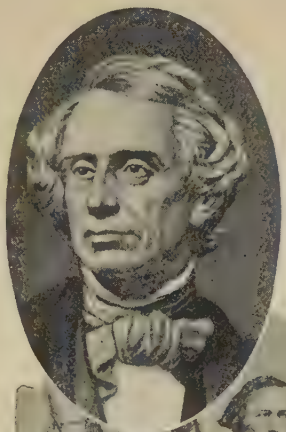
How could you detect the trouble? How could you remedy it? Write out a full story in your Science Discovery Book. This will be of practical value to you.

It is safe to say that modern communication would be impossible without the electromagnet because the electric bell, the telegraph sounder, and the telephone receiver all contain it. If you thoroughly understand its principle and the way it works you can easily understand the telegraph and the telephone. But who was the master mind that first discovered the principle of the electromagnet (Key Picture 13) and who perfected it? That is an intensely interesting story.

3. The Telegraph and How It Works

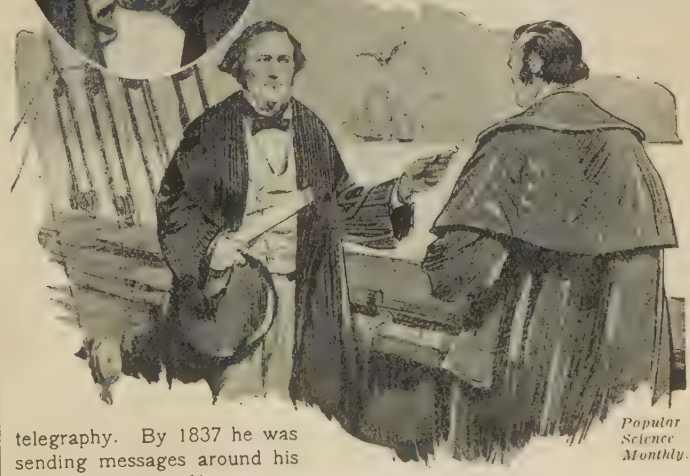
340. Morse and the Telegraph. — In 1815 it was discovered by Oersted (ûr′stĕth) that a magnetic needle could be deflected by passing over it a wire through which a current was passing. In 1831 Michael Faraday (făr′ȧ-dā) discovered that a piece of iron can be made a temporary magnet by winding insulated wire around it and passing a current of electricity through the wire. He called this phenomenon

Samuel F. B. Morse (1792–1872)



While on shipboard returning from England to America, Morse, artist and inventor, conceived the idea of the telegraph. He had his drawings completed and his code invented before he left the ship.

Because of poverty he was obliged to continue his painting in order to secure food and shelter. All surplus earnings he spent on his experiments. Aided by the discoveries of Joseph Henry, he invented the relay so essential to long distance telegraphy. By 1837 he was sending messages around his laboratory. Helped by a young man, Alfred Vail, he perfected his invention and in January, 1838, made public demonstrations in Philadelphia and in Washington, D. C. A bill to appropriate $30,000 for his work failed to pass Congress and Morse went to work again painting portraits. But his faith in his invention was rewarded when, in 1843, the bill was again presented to Congress and passed. With a line stretched from Washington to Baltimore, on May 24, 1844, Morse sat in the Supreme Court Room and sent to Baltimore this message: "What hath God wrought?" At once Morse became known the world over. Nations honored him and rewarded him with wealth. His later days were crowned with the happiness of his good deed done in the service of mankind.



Popular Science Monthly.

electromagnetic *induction.* Thus, electromagnets could be made to work by "making" or "breaking" the circuit.

This idea was developed in America by Professor Joseph Henry. In 1832 Samuel Morse, an artist by profession, stated that the electric telegraph was possible and spent his spare time in experimenting with electricity. By 1835 he had made a fairly successful telegraph (Key Picture 13) and invented a code. By 1861 the telegraph was in use in all parts of the world, and a line from New York to San Francisco was in operation. To-day the country is a network of telegraph lines, and many millions of messages are sent over them in the course of a year. (Study Plate III.)

Demonstration 37 : *Problem: What is the principle of the telegraph sounder?*

Materials: A cigar box with cover removed; two other cigar boxes; a six-inch machine bolt with two nuts to fit; a second

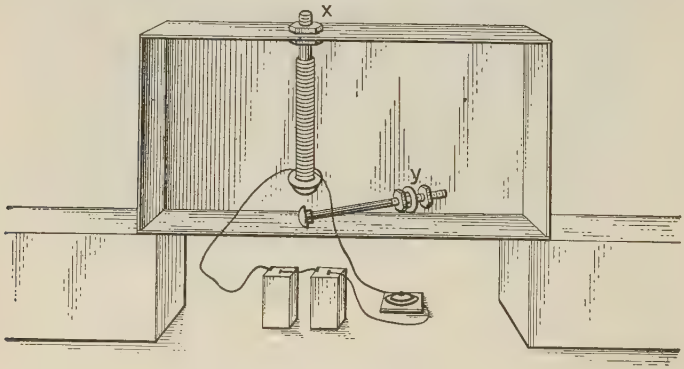


FIGURE 209. — DEMONSTRATION 37.

somewhat lighter machine bolt with nuts to fit; a screw eye large enough to allow the shaft of the smaller bolt to pass through it easily; about 10 feet of No. 24 insulated copper wire; a dry cell battery; and a push button.

Method: Bore a hole through the long side of the cigar box just large enough to allow the shaft of larger bolt to pass through it. Wind the wire about the larger bolt closely in two layers, leaving ends loose. Fit and fasten bolt into hole with nuts at x, as shown

in the diagram. About one inch above the opposite side of the box, fasten the screw eye into the wide bottom of the box at y, about five inches from the head of the larger bolt. Fasten the smaller bolt loosely into place by use of the nuts and adjust it so that its head will come directly below the head of the larger bolt. Now lower the head of the larger bolt until it comes within about one quarter inch of the head of the smaller bolt. Set the cigar box on the ends of the other two boxes as shown in Figure 209. Connect the push button and the two dry cell batteries on the circuit with the ends of the insulated wire. Now break and close the circuit and watch for results.

Observations: What happens to the small bolt when you close the circuit? What happens when you break the circuit? Explain. What have you made of the larger bolt? Explain. Why does the

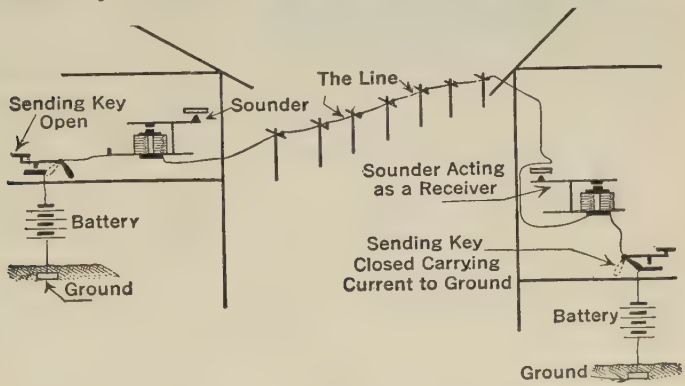


FIGURE 210A. — A TELEGRAPH CIRCUIT.

Follow the path of the current through the circuit. Explain use of each part.

small bolt rise? Is the sound of the small bolt striking the box different from the sound of the small bolt striking the large bolt? You have made here a crude but accurate form of sounder.

Conclusion: What is the principle of the telegraph sounder?

Practical Applications: Examine carefully a telegraph sounder. Compare it with your simple sounder. Connect two dry cells with a sounder and a telegraph key and see if you can explain just what happens. Try to send some letters of the Morse code with your instrument.

341. How the Telegraph Works. — It was Joseph Henry who first found out that tapping sounds could be made at

any desired intervals by simply making and breaking an electric current conducted along a wire, a method now followed in the electric bell. To understand this, study again the diagram of the bell (Key Picture 13). If a key is substituted for the door button and attached in such a way that it can close and open an electric circuit, an armature may be made to give a series of strong taps upon the iron core of the magnet, exactly corresponding with the action of the key.

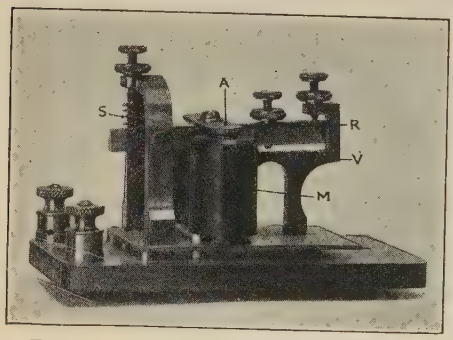


FIGURE 210B. — THE TELEGRAPH SOUNDER.

M, vertical electromagnet (horseshoe type); **A**, armature; **R**, rocker arm; **S**, spring; **V**, anvil.

The electromagnet in the telegraph instrument is called a sounder (Fig. 210b). Why? If the key or transmitter is placed some distance from the sounder, as in the next room, certain taps on the key (Fig. 210c) would mean certain letters of the alphabet. To perfect the idea Morse developed and used with success the Morse code (Fig. 211). Messages were then sent over long distances.

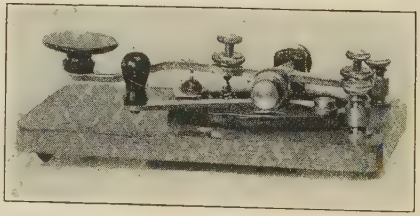


FIGURE 210C. — THE TELEGRAPH KEY. How is it related to the sounder? What does the key do?

In actual practice, it was found that over very long distances the receiving apparatus would not be moved by the current. To overcome the weakening of the message over long distances Morse invented the *relay*, a very important factor

in his final success. The relay is an electrically operated switch. It requires very little current to close a local circuit. The local circuit is independent of the sending circuit and

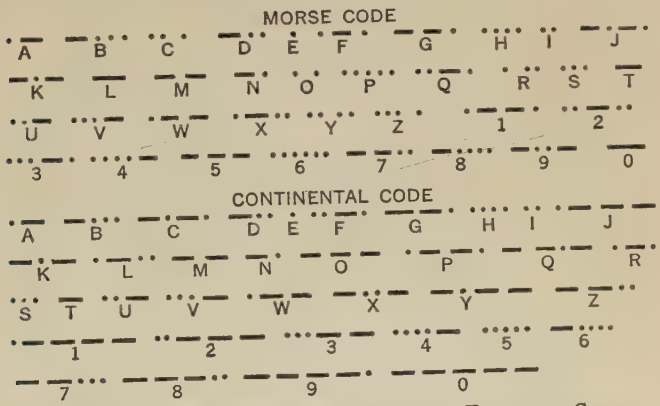


FIGURE 211. — THE MORSE AND CONTINENTAL TELEGRAPH CODES.

Learn one of these codes by practicing with a closed pen knife on two surfaces giving different sounds, or with a real key and sounder.

supplies power for operating the sounder. Hundreds of modifications have been made, but 95% of all instruments used to-day are Morse telegraphs.

4. THE TELEPHONE AND HOW IT WORKS

Demonstration 38 : *Problem: What is the principle of the telephone?*

Materials: Three soft lead pencils; a cigar box; two dry cell batteries; about ten feet of No. 24 insulated copper wire; a telephone receiver; and a watch.

Method: Split the lead pencils so that the lead is exposed through their whole lengths. Cut notches near the ends of two of the pencils all around and down to the lead, exposing it.

Attach the end of the wire to one of these pencils around the lead in the notch. Cut off a foot section of the wire and attach one end of it to the notch of the other pencil. Near the other ends of the two wire-equipped pencils, cut notches down to the lead wide enough

to allow the third pencil to sink down in them so that the leads will touch. Now lay the pencils on the bottom of the upturned cigar box and connect in the two batteries in series and the receiver as shown in Figure 212. Lay the watch on the box near the pencils and listen through the receiver.

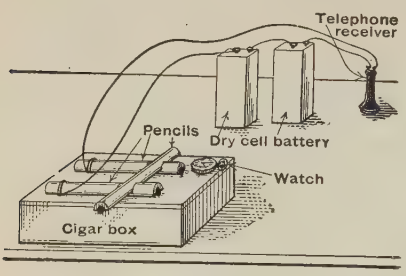


FIGURE 212. — DEMONSTRATION 38.

As you work the experiment determine the use of each part here shown. Could any of these parts be omitted?

Observations: What do you hear in the receiver? Does the watch touch the pencils? How do you account for the passing of the sound to the pencils? Is this a real sound or is it a series of vibrations which pass to the pencils? What effect does the watch have on the carbon in the pencils? What is the use of the cross pencil? Does the watch cause the box bottom to vibrate at all parts at exactly the same rate? Explain. This means that there will be some variation in the impulses sent to the receiver. A rapid series of vibrations is caused in the current to the receiver. These vibrations are caught and transmitted by the diaphragm (a thin vibrating disk), thus reproducing the sounds.

Conclusion: What is the way the telephone works?

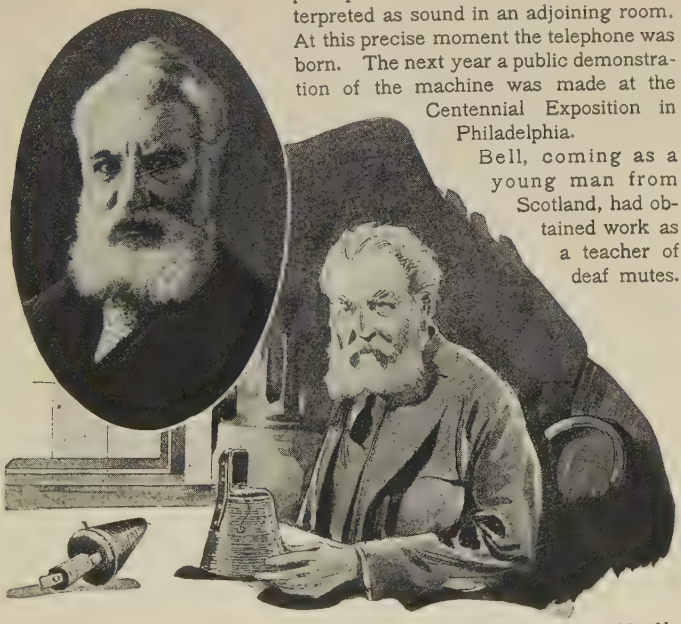
342. The Telephone. — On February 14, 1876, Alexander Graham Bell, a naturalized American citizen, patented the first telephone. In the same year the instrument was tested out at the Centennial Exhibition in Philadelphia. Dr. Bell in company with Thomas A. Watson invented an improved diaphragm which was connected to a soft iron core in front of an electromagnet. By connecting two such diaphragms through a wire and sending over this wire a strong electric current, the voice vibrations were carried from one disk to the other. This was the real beginning of the telephone.

343. How the Telephone Works. — Dr. Bell early discovered that when an electric current is passing over a wire, the human voice can cause marked variations in this cur-

Alexander Graham Bell (1847–1922)

On June 2, 1875, in a little shop in Boston, Alexander Graham Bell and a companion by the name of Thomas Watson were hard at work over a bit of mechanism. Suddenly an accidental movement of the parts produced a vibration which Bell interpreted as sound in an adjoining room. At this precise moment the telephone was born. The next year a public demonstration of the machine was made at the Centennial Exposition in Philadelphia.

Bell, coming as a young man from Scotland, had obtained work as a teacher of deaf mutes.



Popular Science Monthly.

Under the inspiration of Joseph Henry he began to think about reproducing sound at a distant point. He worked at this without stopping until the eventful June 2.

Demonstrations in the cities of the country soon followed. Finally the Bell Telephone Association was organized to develop his invention. The company was involved in more than 600 suits of patent infringements and won them all. Bell's patent is now called the most valuable single patent ever issued.

Transcontinental and transoceanic communication is now a common event. In New York City alone there are more than one million telephones, with more than $3\frac{1}{2}$ million miles of wires carrying more than 500,000 calls between 10 A.M. and 11 A.M. each day.

Bell was a great scientist and his life was one of service to humanity.

rent. He also discovered that many kinds of currents pass over a telephone wire, but an undulating (in the form of waves) current is the one best fitted to carry the vibrations caused by the voice. Thus the voice does not travel along the wire at all, but the undulating currents are patterned on

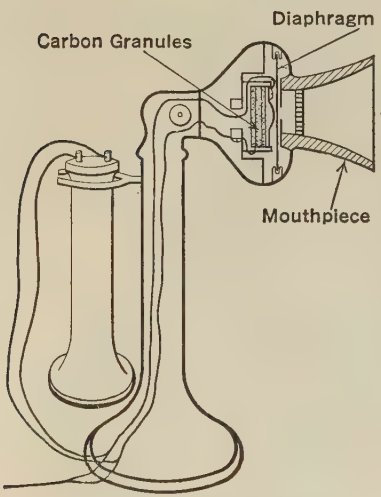


FIGURE 213A. — THE TELEPHONE TRANSMITTER.

Note the location of the carbon granules. What causes the movement of the diaphragm? Why is its movement important?

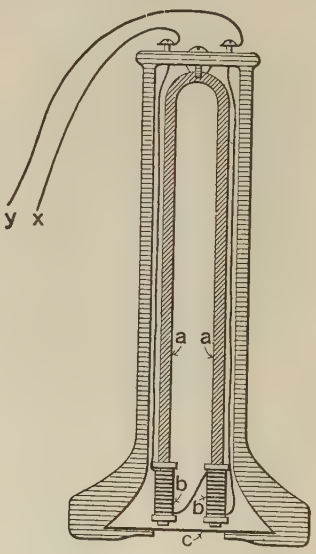


FIGURE 213B. — THE TELEPHONE RECEIVER (INTERIOR).

a, **a**, horseshoe magnet; **b**, **b**, insulated wire coils; **c**, diaphragm; **x**, **y**, wires carrying electrical impulses to the coils. What does the diaphragm do here?

the voice changes and are interpreted as sound at the receiving end of the line (Plate III).

In 1915 the writer sat in a room in San Francisco and listened to weather reports, phonograph records, and the waves beating on the ocean beach in New York City. These sound impulses came by way of Atlanta, New Orleans, and San Diego, a distance of nearly 5000 miles. The interval

of time between sending and receiving was one-fifteenth of a second.

No one can realize the tremendous sensitiveness of the telephone. The diaphragm of the transmitter will vibrate through an amplitude of but one ten-millionth of an inch.

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FIGURE 214A. — AN EARLY TELEPHONE EXCHANGE.

If the energy used in raising the receiver from the hook one foot were changed into electrical energy it would be sufficient to vibrate the diaphragm of the receiver continually for 100,000 years.

Study Figures 213a and 213b until you understand them well enough to explain them to the class.

New York Telephone Co.

FIGURE 214B. — A MODERN TELEPHONE EXCHANGE.

What are the important differences between this and the exchange shown in Figure 214a. Account for these differences

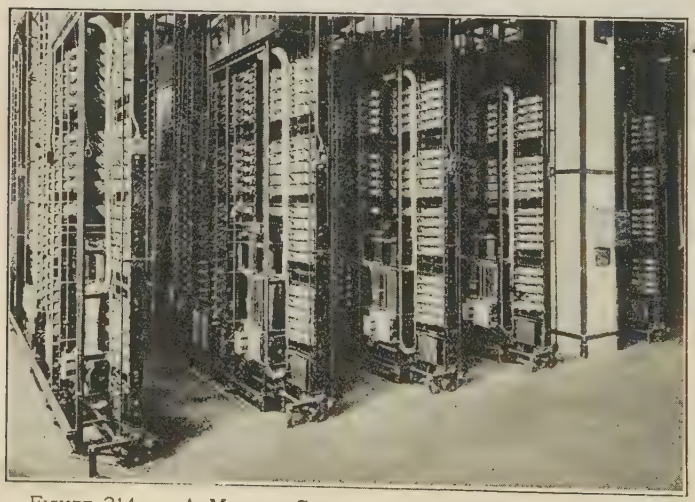


FIGURE 214C. — A MACHINE-SWITCHING EXCHANGE, — DIAL SYSTEM.

No human hand controls this exchange, but electrical hands do actually make the connections.

5. The Wireless Telegraph

344. Telegrams without Wires. — The wireless telegraph has a Morse-like key and sounder, but it requires no wire connections between its sending and receiving stations. The messages are carried out through the ether by electromagnetic waves, produced by the telegraph itself, from power supplied by an alternating current. Dr. Hertz (hĕrts), in

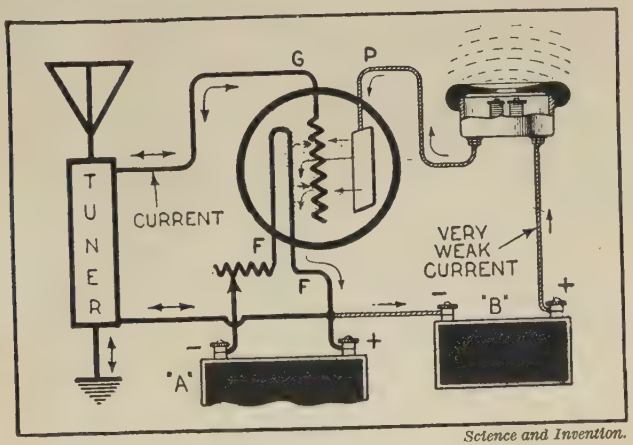


Figure 215a. — A Modern Wireless Circuit.

1887, discovered how to produce these waves and Marconi, an Italian scientist, following his lead, discovered how to send them over long distances. In 1890 Dr. Brady had invented a *coherer* (Fig. 215b) which picked up these waves. This was improved by Marconi and with the use of a vertical aërial, which collects the electrical waves and sends them to the coherer, the essentials of the wireless telegraph were complete. On December 12, 1901, Marconi sent his first messages across the Atlantic Ocean.

345. How the Wireless Telegraph Works. — The Marconi (sending) apparatus consists essentially of an induction coil, the secondary terminals of which are attached to the aerial

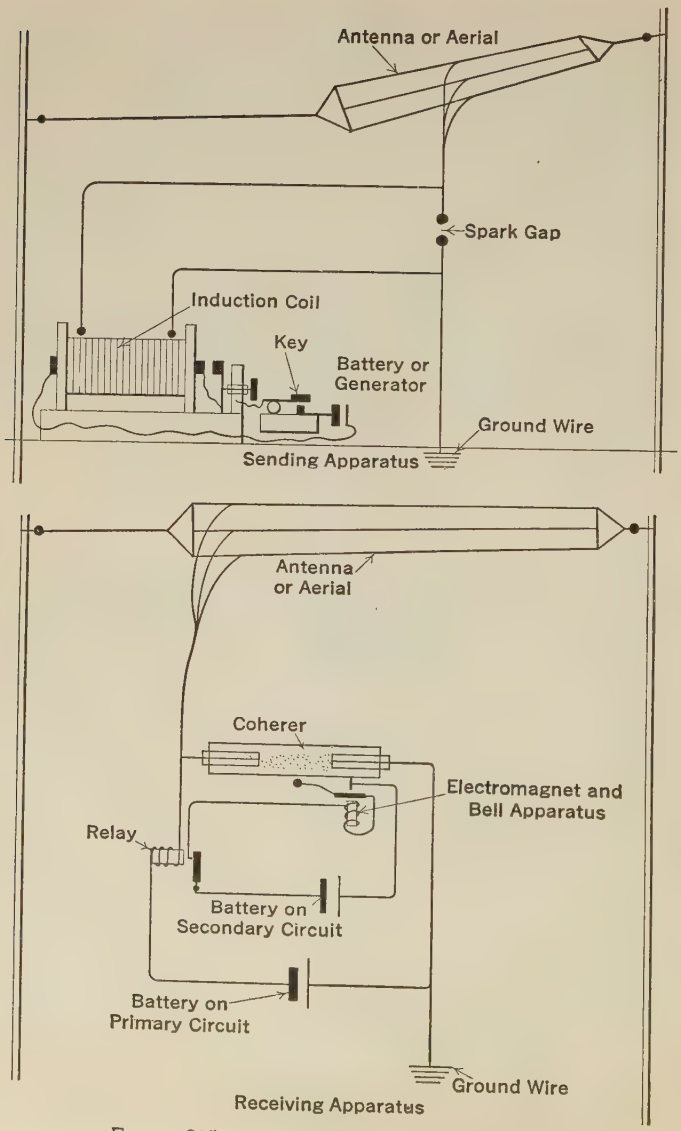
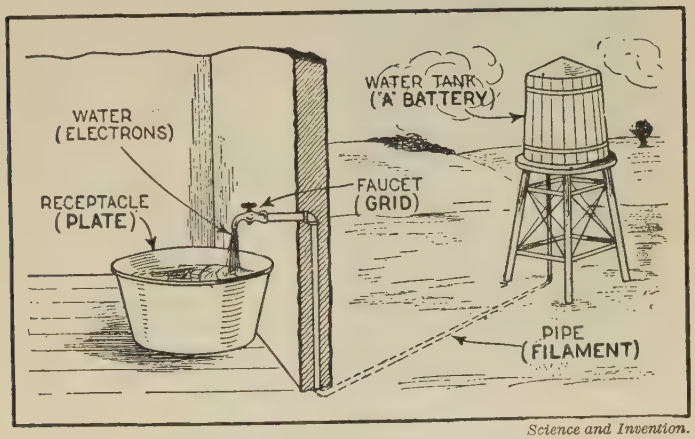


FIGURE 215B. — AN EARLY WIRELESS CIRCUIT.

and ground wires respectively while the primary terminals are attached through a key to a battery (or generator). Every time the key is closed, a discharge takes place across the spark gap, and electrical waves are sent out from the aerial. These electrical waves travel in all directions and produce electrical oscillations in the aerial of the receiving



Science and Invention.

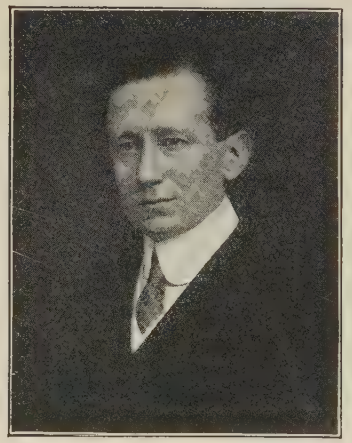
FIGURE 216. — HOW THE WIRELESS WORKS.
Study this picture and explain the circuit.

apparatus, which pass through the coherer to the ground and have the effect of reducing the electrical resistance of the coherer. A local battery is thus enabled to operate the relay connected with the sounder or buzzer.

6. THE WIRELESS TELEPHONE

346. The Modern Marvel. — The wireless telephone (more commonly called the radiophone or, simply, radio) is a natural consequence of the telegraph, the telephone, and the wireless telegraph. It is like them in its general principles of construction and operation, and, like them, depends upon the production of electrical waves for the success of its performance. Two things make it superior to them, —

Guglielmo Marconi (1874-)



Piecing together the discoveries of many men who had lived before and during his own time, Marconi gave the wireless telegraph to the world.

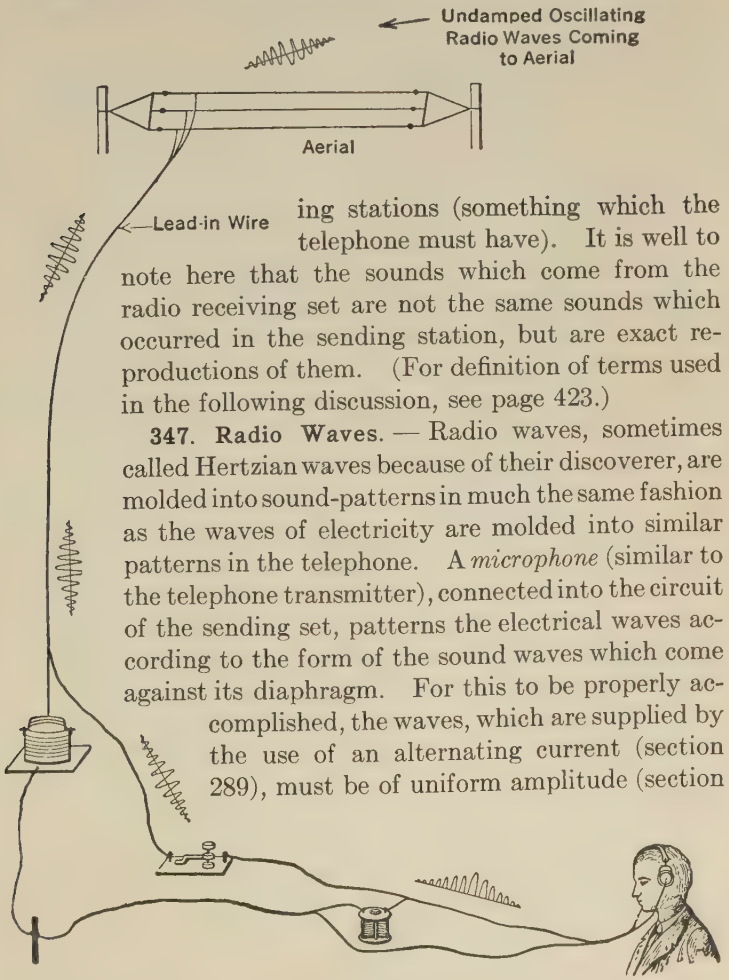
In Newfoundland, December, 1901, he sent up a kite equipped with a wire which led down into a room and on into a telephone receiver. After a long wait there came three faint taps, • • •, the letter S in the Morse code. It was repeated. The ether waves had carried this signal across the Atlantic from England and the wireless telegraph was born.

Using all the appliances and discoveries of Hertz, Clerk-Maxwell, Bundy, and others, Marconi set up a laboratory in his father's yard and began his experimentation. He improved his apparatus and invented the aërial. Convinced that he had discovered the key to the problem, Marconi went to England and in 1899 sent messages across the English channel. In 1900 he sent messages all over Europe. In 1901 he wirelessed to America.

On page 414 is a diagram of one of the first circuits used by Marconi. Note the important parts and try to determine the exact function of each.

With selective tuning, wireless began to serve the world in business, in government matters, and in saving lives. To Marconi belongs first honor for this wonderful contribution to the happiness of the human race.

(1) its ability to reproduce sound vibrations (something which neither form of telegraph can do), and (2) the fact that a connecting wire is unnecessary between the sending and receiving stations (something which the telephone must have). It is well to note here that the sounds which come from the radio receiving set are not the same sounds which occurred in the sending station, but are exact reproductions of them. (For definition of terms used in the following discussion, see page 423.)



347. Radio Waves. — Radio waves, sometimes called Hertzian waves because of their discoverer, are molded into sound-patterns in much the same fashion as the waves of electricity are molded into similar patterns in the telephone. A *microphone* (similar to the telephone transmitter), connected into the circuit of the sending set, patterns the electrical waves according to the form of the sound waves which come against its diaphragm. For this to be properly accomplished, the waves, which are supplied by the use of an alternating current (section 289), must be of uniform amplitude (section

FIGURE 217. — THE CIRCUIT OF A CRYSTAL RADIO SET.
Find the crystal detector; the ground line; the condenser.

73). The current which they carry must *oscillate* (change its flow back and forth) at a high speed, that is, it must have a *high frequency* (section 289). To produce such waves the sending circuit must include *vacuum tubes* and a *condenser* connected in series with an *inductance*. The waves thus produced are *undamped* (Fig. 218a) and their *oscillations* form one *continuous wave*. The *amplitude* (we may think of amplitude as the distance from the end of a plus wave to the end of a minus wave) of these oscillations depends upon the intensity of the sound vibrations (section 72) which press against the diaphragm of the microphone. (Key Picture 13, 3c.)

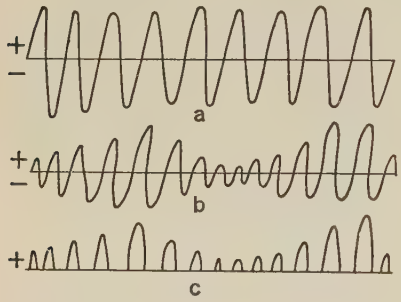


FIGURE 218A. — UNDAMPED OR CONTINUOUS WAVES.

An undamped wave not modulated is shown at **a**; at **b** the wave is modulated; and at **c** the wave is rectified as well as modulated.

The change in the amplitude of parts of the continuous wave is called *wave modulation*. What actually happens is that the pressure of the sound vibrations against the diaphragm is transmitted to the carbon button at the center of the diaphragm. This pressure causes changes in the current strength. The resulting changes in amplitude of some of the oscillations correspond exactly to the changing sound vibrations.

348. The Receiving Set. — The receiver is *tuned in resonance* with the sending set and operates in much the same fashion. Its circuit includes a device, called a *detector*, for *rectifying* the current by changing it from alternating to direct. A coherer, a *crystal*, or a vacuum tube is used for this purpose. So that they may be heard, the high frequencies of the sending set are reduced to *audio frequencies* in the earphones or loudspeaker.

349. The Vacuum Tube. — The vacuum tube is the most efficient device for rectifying incoming waves, replacing to a considerable extent the earlier use of the crystal. It also greatly increases the sensitiveness of the radio receiver and provides the only known method of amplifying radio signals. It looks very much like an ordinary incandescent bulb but in addition to its tungsten filament it has a small ladder-like at-

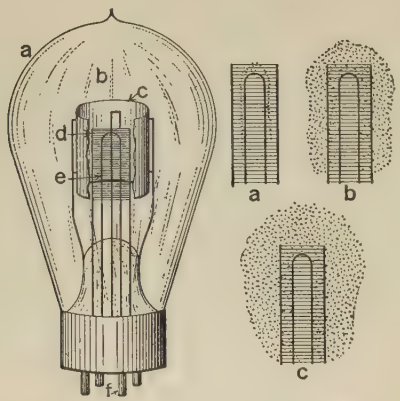


FIGURE 218B. — A VACUUM TUBE.

Left: **a**, bulb; **b**, vacuum; **c**, plate; **d**, grid; **e**, filament; **f**, contact points. *Right:* **a**, electrons in a cold wire; **b**, in a wire heated to about 3000° F.; **c**, in a wire heated to about 4000° F. Within certain limits, the hotter the wire, the better the results.

tachment, the *grid*, and a pair of metal plates which surround the grid and the filament. Its services depend principally on the activities of the electrons (pages 289 and 290) which compose its filament.

350. Other Elements of the Radio. — Other important elements in the structure of the radio are the aërial, the inductance, the condensers (fixed and variable), coils, rheostat, ground, and loudspeaker or earphones. In the receiving set where tubes are used in place of the crystal the tubes vary in number, but aërial, condensers, and loudspeaker or

earphones are used just as in the crystal set. In addition there are a large storage battery, a rheostat, a small B battery, and grid leaks in ratio to the number of tubes used.

Suppose you now follow the oscillations through the set by carefully studying Figure 219.

If you have carefully traced the path of the electric waves through the set, you should now have in mind the essentials of the radiophone. It is a complex piece of apparatus which makes it all the more wonderful and shows man's inventive genius in carrying on the world's work. Get in touch with a crystal or vacuum tube set and with your book in hand, study its parts, watch it operate, and ask questions of the operator. A little study and a little practice will put you in a position to get a set for yourself. By

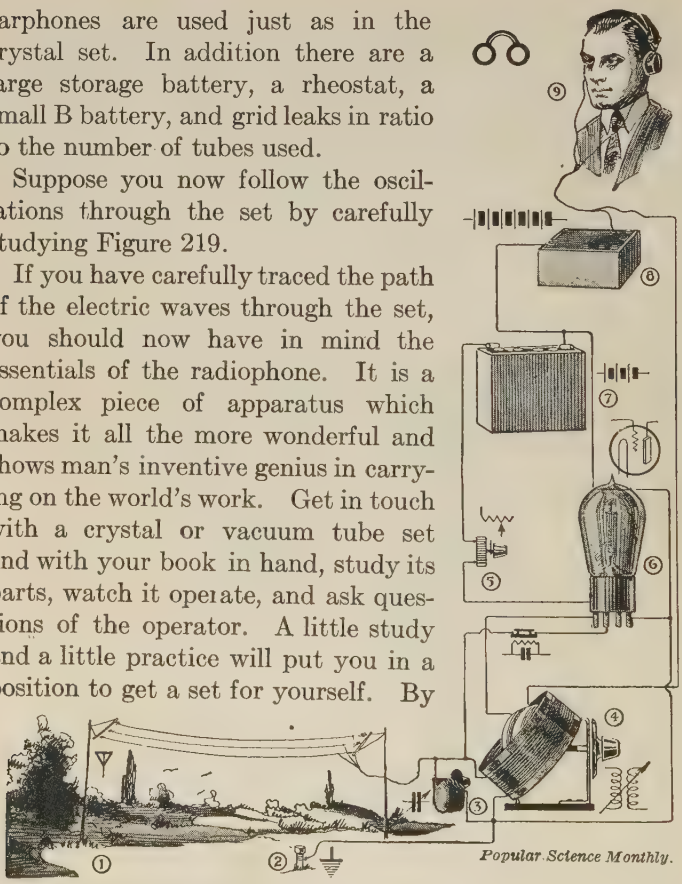


FIGURE 219. — A VACUUM TUBE SET.

① and ②. Aerial and ground absorb the electromagnetic energy of broadcast radio waves. ③. Condenser is used to help tune in on any one station. ④. The tuner admits only waves of a certain frequency, — it lets in one station and cuts off others. ⑤. Rheostat controls amount of current going into the detector tube. ⑥. Detector tube changes high frequency waves to lower frequency waves which are alike. ⑦. "A" battery supplies current to heat filament in vacuum tube. ⑧. "B" battery supplies direct current to carry electrical vibrations from detector to earphones. ⑨. Sensitive diaphragms in earphones are vibrated by electric currents varying in accordance with vibrations of sounds being broadcast.

buying parts separately, you can construct a set at a very low cost. It is impossible to give you every detail of the radio to-day, because every day brings new ideas and improvements. You are asked to read the latest popular books devoted to this subject.

351. Radio and the Work of the World. — Every day sees new additions and improvements to the radiophone. Each article and book printed about it is behind the times before it comes from the press. Of what great value is the radiophone in the work of the world? Its greatest value is

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FIGURE 220A. — PANEL BOARD, UNIT DIALS, VERNIERS, AND RHEOSTAT CONTROLS.

in making people more contented because they feel in closer touch with great artists in every line of work. Especially is this so with the farmer or man living in the small town. It makes men work better because it gives them a richer life. Colleges are giving courses "on the air" and lecturers instruct multitudes on every conceivable subject. For invalids and shut-ins radio is a great blessing. Sermons are now broadcast each Sabbath to many who never enter a church. The possibilities of radio in the world of commerce, transportation, and special industries have yet to be fully realized (Plate III).

The sending of pictures recently by radio opens up another new use of the invention. Its great function will be to knit more closely the whole world in a deeper feeling of brother-

hood. If this will tend to prevent wars, then it will be one of the greatest blessings ever given to mankind.

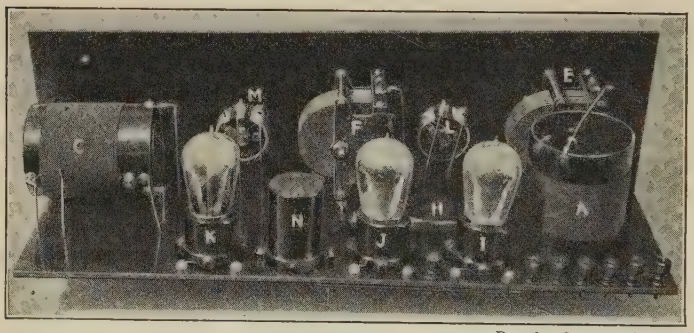

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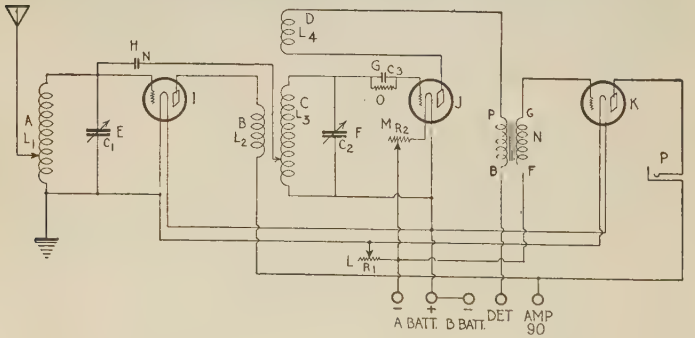
FIGURE 220B. — REAR VIEW OF A THREE-TUBE SET.

A, input coil; **C**, detector grid circuit coil; **E**, **F**, variable condensers; **I**, **J**, **K**, standard sockets, **L**, 15-ohm rheostat; **M**, 30-ohm rheostat; **N**, audio-frequency transformer.



Popular Science Monthly.

FIGURE 220C. — THE HOOK-UP FOR THE ABOVE SET.

B, radio-frequency coil (not shown above), **D**, detector tickler coil (inside **C** above); **G**, grid condenser, .00025 microfarad with clips for grid leak; **H**, neutralizing condenser, about .0003 microfarad; **O**, grid leak, two megohms; **P**, open circuit jack; **N**, audio-frequency transformer (**P** to plate, **G** to grid, **F** to filament, **B** to battery); R_1, R_2, rheostats; C_1, C_2, variable condensers.

Identical letters refer to identical parts, though the parts themselves are reversed because the diagram represents a front view of the set.

RADIO TERMS

(Other radio terms of the text are defined as they occur.)

Aërial (Antenna): A system of wires used to transmit or receive electromagnetic waves.

Amplify: To increase the audibility of a radio signal.

Amplitude: The height of a wave. Wave amplitude depends on the strength of the current.

Audio Frequency: A frequency of 10,000 cycles or less (p. 334).

Coherer: A device employed to detect electric waves. It consists of a small glass tube in which loosely touching metallic particles stick closely to one another when under the influence of an electromagnetic wave, thus momentarily completing a local electric signalling station.

Condenser: An instrument for accumulating or concentrating electricity. It consists of two or more conducting plates separated by an insulating medium such as air, glass, or mica. The variable type of condenser sharpens the action of the impulses on the diaphragms of the phones, making the signal distinct.

Damped waves: Waves which start out with a high amplitude that gradually tapers off to zero because of resistance to the wave.

Detector: A device for allowing alternating (or oscillating) radio waves to pass along a circuit in but one direction. Either the crystal or the vacuum tube may be used for this purpose in the radio circuit.

Grid Leak: A device for getting rid of excess charges on the grid.

Ground: The contact of a conductor with the earth, usually made by a wire running from the station to the ground.

Inductance: A device in the antenna circuit for adjusting the circuit so that it will respond to waves of different lengths.

Microfarad: A unit used in measuring electrical capacity.

Megohm: One million ohms.

Plate: A device in the vacuum tube for receiving the flow of electrons from the filament.

Tuned in resonance: A phrase used to indicate that sending and receiving stations are adjusted to the use of the same wave length.

Undamped waves: Waves of uniform strength whose amplitude varies only as the current is made to vary by the diaphragm.

Vernier: The small scale on the dials.

Wave length: The distance between waves as they leave the transmitting station.

REVIEW OUTLINE

1. Relation of Communication to: (1) Business; (2) transportation; (3) news.
2. Modern Communication depends upon the: (1) Electric bell; (2) electromagnet. Principle of each.
3. The Telegraph in relation to the discoveries of (1) Oersted (1815); (2) Faraday (1831); (3) Henry (1831); (4) Morse (1835).
4. The Principle of the Telegraph. Parts: sounder, key, electrical current, relay; functions of each.
5. Modern Improvements in the Telegraph.
6. The Principle of the Telephone. Discoveries and work of Alexander Bell (1876). Parts of the telephone: (1) transmitter (diaphragm, carbon particles, electromagnet, wire); (2) receiver (diaphragm, electromagnet, wire). Function of each part. Importance of the telephone in everyday life.
7. The Wireless Telegraph. Discoveries of Hertz (1887); Brady (1890); Marconi (1901).
8. The Principle of the Wireless Telegraph. Parts: sending key; electrical current; spark gap; coherer; relay; tapper and sounder; tuning apparatus; aërial. Function of each part.
9. The Wireless Telephone compared with the three other forms of electrical communication.
10. Sound reproduction in the Radio: Requires a rectified alternating current of high frequency. Type of electrical wave used: Waves of uniform amplitude (undamped), — a continuous wave, modulated. How produced. Wave length. Tune in resonance. Receiver.
    Apparatus: Important elements; current, aërial, microphone, vacuum tubes or crystal, coupler, batteries, rheostat, grid leak, inductance, condensers, coils, and loudspeakers or earphones.
11. Present and Future Importance of the Radiophone in the Work of the World.

SUMMARY

Among early peoples *communication* was possible only by means of signs, fires, smoke, torches, cannon, etc. Messengers on foot or on horseback were the surest and swiftest means of land communication during all known history down to the year 1835, not quite one hundred years ago.

With the invention of the *electromagnet* by *Michael Faraday* in 1831 and the sending of *code impulses* on a *wire* by an *electric current* in 1835, the *telegraph* came into existence. Samuel Morse at once

made the whole world a different place in which to live. While Morse owed much to previous experimenters, so present-day scientists in telegraphy owe almost everything to Morse, because all instruments used to-day are in essentially the same form in which he first made them. The telegraph has made the whole civilized world no larger to-day than Manhattan Island was during the eighteenth century.

In 1876 *Alexander Graham Bell*, using the findings of previous experimenters, was able to send electrical impulses produced by the human voice over a wire for the first time, with the aid of electric currents, electromagnets, and a *sensitive diaphragm*.

In *1901 Marconi*, using the findings of *Hertz*, *Brady*, and *Morse*, invented the *wireless telegraph*. This sends electrical waves into the air from tall *aërials*. These waves are sent out in groups of fixed order and number representing the dots and dashes of standard codes. They are received by an apparatus which reproduces the dots and dashes of the sending set.

The *wireless telephone* or *radiophone* is a natural consequence of the three other forms of electrical communication. By its production of *undamped* electrical waves of high frequency it is able to reproduce sounds at long distances from their source. Its waves are *modulated* (molded) into the sound patterns by the *microphone* and are sent out with a predetermined *length* to be picked up by a *receiver* which has been *tuned* in *resonance* with the sending set. This receiver reduces the waves to *audio* frequency.

The alternating current which supplies the waves is *rectified* by a *crystal* or *vacuum tube*. The radio is a wonderful contribution to the forces which perform the work of the world.

Remember that:

1. Electricity made modern communication possible.
2. Modern rail transportation was impossible until the telegraph was invented.
3. Modern industry and commerce are largely due to the development of the telephone and telegraph.
4. The invention of the electromagnet made the present telephone and telegraph possible.
5. The greatest invention of the present day is the radiophone.

THOUGHT QUESTIONS

1. Why must magnets be used in telegraphing and telephoning?
2. What one man laid the foundation for the telephone and telegraph? How did he do it?

3. What is the advantage of the telephone over the telegraph? of the telegraph over the telephone?

4. Which is more reliable, the wire telephone or the wireless telephone? Give reasons for your answer.

5. Why is it advantageous to run a strong electric current over a wire in order to carry on communication of any kind?

6. What is the importance of the diaphragm in the telephone? Why is none used in the telegraph?

7. In the radiophone what apparatus must be used that is not used in the telegraph or telephone? Explain.

8. What is "tuning" in wireless communication? What is its importance?

9. Does the human voice travel along the wire in telephoning? If it does, why is it so often unfamiliar? If it does not, how can one recognize a voice at all?

10. Show how the principle of the electric bell is used in the telegraph.

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Carson. History of the Telephone. McClure Co.
Collins. The Radio Amateur's Handbook. T. Y. Crowell Co.
Collins. The Book of Wireless. D. Appleton and Co.
Henley. 222 Radio Circuit Designs. Henley.
Holland. Historic Inventions. G. W. Jacobs and Co.
Lescarboura. Radio for Everybody. Scientific American Press.
Lewis. The A B C of Vacuum Tubes. Henley.
Mills. The Magic of Communication. American Telephone Co.
Towers. Masters of Science. Harper and Bros.
Yates and Pacent. Complete Radio Book. Century Co.

PART IV

THE SOURCE OF ALL ENERGY

Nothing is lost on him who sees
With an eye that genius gave;
To him there's a story in every breeze
And a picture in every wave.

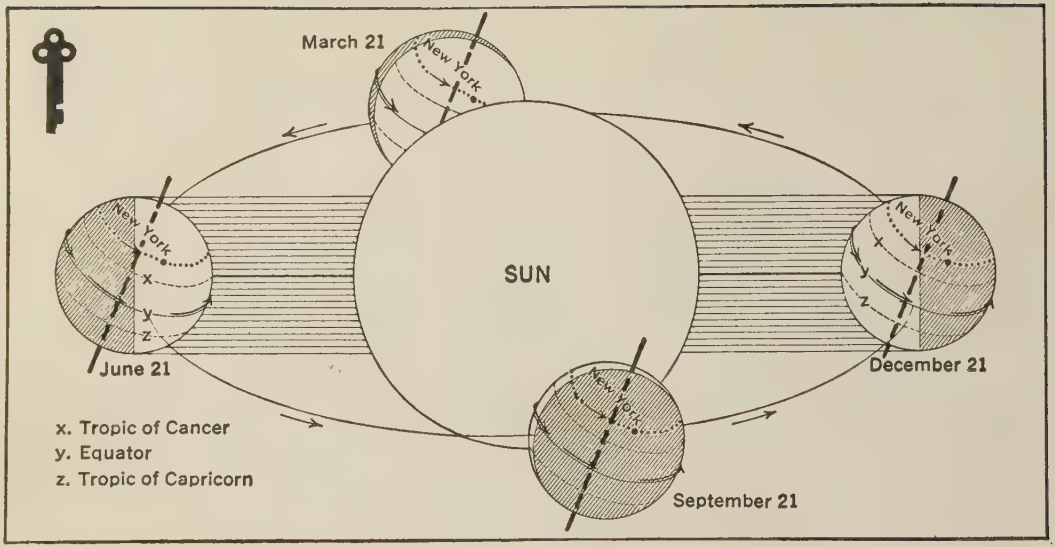
— *Moore.*

In Part III a detailed study of several important industries showed you that industries vary according to climate, to the ease with which raw materials are secured, or to nearness to easy means of transportation, but that they all use some form of energy. Motion is necessary in every industry to enable the machinery to change raw materials into finished products.

In some industries this motion is produced by expanding steam, in others by exploding gases, and in still others by falling water. Most industries get their power from either fuel (coal or petroleum) or water. The question now facing you is: What is the source of all this industrial power? Where did the coal and oil and water get the energy in the first place? Where does the power come from that turns the windmills in Holland where water power is not to be had?

On the other hand, you may also ask where the energy comes from when high tides, destructive floods, or devastating tornadoes destroy life and property? What causes a difference in the seasons? What makes things grow?

You have had hints in former chapters that the sun had something to do with these actions. In the next two chapters you will try to discover and understand some important facts about the sun. You will determine whether these hints were true or false.



KEY PICTURE 14. — WHAT CAUSES OUR SEASONS?

Note that in June New York goes through a greater distance in the light than in the dark area. Which is the longer, — the day or the night? Explain. What causes day and night? During June much heat is absorbed by the earth during the day. Explain. What, then, causes summer? What causes winter? (See December position of earth.) Now determine why the days and nights are of equal length in March and September. Where do the sun's direct rays (heavy black lines) strike the earth in June and December? Where are the rays the least direct? What causes our seasons?

CHAPTER XIV

THE SUN AS THE SOURCE OF ALL ENERGY

The spacious firmament on high,
With all the blue ethereal sky
And spangled heavens, a shiny frame
Their great Original proclaim.

—*Addison.*

Did you ever think of the sun as doing work? How do you suppose it keeps the planets in place swinging around their orbits, if it does not exert force? What do you actually know about our solar system? Would you really like to know more about it? On a clear night you see the stars. What are these stars, anyway? Would you like to know? In winter the nights are long and the days short, in summer they are the opposite. Do you know what makes this difference in the length of day and night? Then again, we have summer and winter seasons. Why? Do you suppose that the seasons have any effect upon living things, including yourself? You like a moonlit night. Why does the moon shine? What has the moon to do with the tides? You own a watch. How do you tell time? What determines what 6 o'clock is? These are all interesting questions and are all answered in this chapter.

Some Practical Questions :

1. In each of the chapters you have already studied, find an example of work done by the sun.
2. What makes it possible for the sun to do work?
3. How does the sun do work on the earth and moon?

4. Show how the paper upon which this sentence is printed could not have been made or printed without the sun.

5. Imagine this world without sunlight. Then tell what would or would not exist upon it and what would or would not be done upon it.

Home Problem. — By the use of a stick set in your yard, find out the length of the shadow cast by it at each hour during some Saturday. Indicate each hour mark with a nail or other marker. Now tell the time of day with your stick and its shadow. Try half-hours and quarter-hours and verify your guess by use of the clock. Note after a few days if your shadow clock is keeping as good time as when you started it. Account for this. Correct your clock and begin again.

FIGURE 221. — THE RADIOMETER.
Note especially the vanes.

Field Problem: Determine the (1) purpose, (2) advantages, and (3) disadvantages of daylight saving time. What are its effects upon people in the country and in the city? Get opinions from different people on this subject before making your report.

1. How the Sun Does Work

352. The Sun as the Engine of the Universe. — Have you ever noticed in the window of the jeweler's shop a little glass instrument with silvered wings or vanes? This is a *radiometer* (rā′dĭ-ŏm′ē-tēr) (Fig. 221). The force that makes these vanes turn is the same that causes steel rails to "buckle." The sun is an enormous engine. It runs the world.

Suggested Experiment. — Remove a radiometer from its box and examine its construction very carefully in a part of the room far removed from the direct rays of the sun. After learning just how it is made and how it acts when given a rotary motion, place it on the window sill in direct sunlight. Watch for results. Take it to the back of the room. Watch results. Remembering your discussion of heat distribution in Chapter VIII, why do you think the silvered sides of the vanes move toward the sun's rays?

Since dark colored surfaces absorb heat more readily than light colored surfaces, which surface of each vane will be the warmer? What effect will the warmer surface have upon the molecules of air touching it? Will they strike the dark surface of the vane? Which surface of the vane will be hit the harder?

How does the sun cause motion in the radiometer? How does the sun do work in the radiometer? How could one cause a concentration of the sun's heat on the radiometer? How would this affect the motion of the vanes? Solar engines have been made and tested in the western part of the United States. Steam engines have been run by the sun's rays, iron has been melted, bread has been baked, and potatoes cooked. Explain.

353. Chemical Action of Light. — Wet two pieces of light-colored cloth in water and then place one in the bright sunlight for a whole day and the other in a dark closet for the same length of time. You will be surprised on comparing them when dry to see that one of them has changed in color. Which one has changed and why?

Get a piece of blueprint paper and, laying a leaf or other object upon it, expose it to the sun for a short time. Wash this paper in water and allow it to dry. What do you see? What caused this result?

Why are wall papers often darker behind pictures on a wall than beside these pictures or around them? Procure a piece of photographic (fō′tō-grăf′ĭk) paper and print a picture from a negative. Regular photographic paper is coated with a silver salt which, when "developed," is changed to silver and darkened where the light rays strike it through the light parts of the negative. The darker parts of the negative do not allow as many light rays to pass through, so the salt is little affected. Fixing the salt causes the picture to remain without fading. Thus light does work in photography.

You can perform, if you desire, another experiment in your own home to show the power of the sun to do work.

Suggested Experiment. — Get a reading or magnifying glass and a piece of tissue paper. Focus the sun's rays through the glass upon the paper so that the bright spot is about one-eighth of an inch

in diameter. Hold the apparatus steady and watch for results. Explain to the class what happens, give your reasons, and write up the experiment in your Science Discovery Book.

2. Our Solar System and Its Neighbors

354. Our Sun and Its Planets. — Our sun, the center of our solar system, is a star not so large as any one of those we can see on a clear, dark night. It is a highly heated and luminous body 1,300,000 times the size of our earth. Its average distance from us is about 93,000,000 miles. Even at this distance its heat and light are intense, especially in

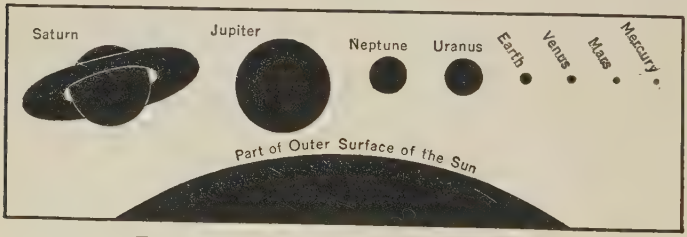


Figure 222. — Our Sun and Its Planets.

Note how the earth compares in size with the sun. Learn the names of the planets in order of size. Which planet is the largest? To get a good idea of the size of the sun lay a sheet of paper along the lower edge of the illustration and complete with a pencil the circle of the sun.

the summer time, yet we receive but about one two-billionth of its energy, which passes off into space in every direction. Some scientists consider the sun an electric furnace, — a great ball of electrical energy. Others think it a storehouse of radium.

Around our sun through the action of centrifugal (sĕn-trĭf′ū-găl)[1] and centripetal[2] (sĕn-trĭp′ē-tăl) forces, revolve eight planets[3] all differing in (1) size, (2) distance from the

[1] Centrifugal force : a force which tends to throw a body away from a center about which it is revolving.

[2] Centripetal force: a force which tends to draw a body towards a center about which it is revolving.

[3] Planet: a wanderer in space.

center of the solar system, (3) the velocity of their motion through space, and (4) the length of their orbits (their path about the sun). Each one has (5) a different length of year and (6) of day, (7) different kinds of seasons, (8) a different climate, and (9) a different temperature. Can you explain this? Study the planets named in Figure 222 in the order of their distance from the sun.

The laws which describe the action of these planets were first explained by Galileo and Sir Isaac Newton.

355. The Constellations. — Beyond the few planets which we can see with the unaided eye are the thousands of stars

FIGURE 223. — SOME OF OUR CONSTELLATIONS.

How many stars do you see here? How many constellations? How could they have been named? Of what value are they to man?

or suns set like pearls in the black vault of the heavens. They look to be millions in number but we are told that there are only about 4000 visible to the naked eye on a clear night (Fig. 223). The nearest star is about 300,000 times as far away from us as our sun. Some stars are capable of giving off 10,000 times as much light and heat as our sun. (To get an idea of their sizes compare the star Canopus (kȧ-nō′pŭs) with our sun as shown in Figure 224.) The apparent groupings of these stars are called constellations (kŏn′stĕ-lā′shŭnz).

356. The Milky Way. — Across the heavens from one side to the other is a tremendous group of stars so numerous that they give a milky appearance to the portion of the sky which they occupy. There are probably at least 500,000,000 suns in this great group of constellations and because of their grandeur they have been given the name of a galaxy (găl′ăk-sĭ), or the Milky Way.

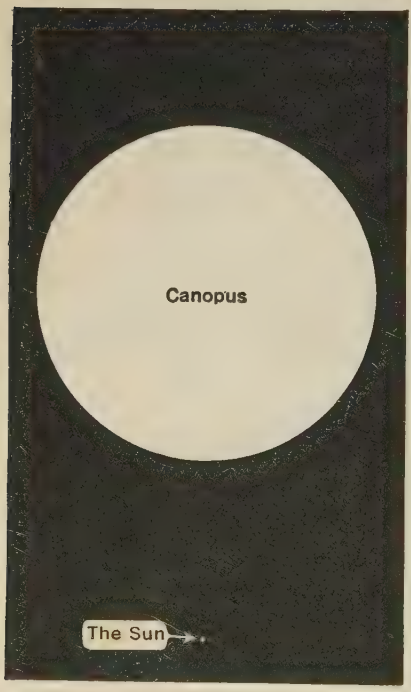


FIGURE 224. — OUR SUN AND OTHER SUNS.

Compare the size of our sun with that of the star Canopus. Our whole solar system would go inside of this one star alone. This gives you some idea of space in the heavens, and of how small we really are after all.

3. CAUSES OF DAY AND NIGHT

357. Day and Night. — We say that the sun rises in the east every morning, but does the sun really rise? Does the sun move or do we move? What causes day and night? The earth turns about its own axis as it follows its path about the sun. Keeping this in mind, construct an apparatus which will explain day and night.

358. Variations in the Length of Day and Night. — With the axis of the earth in a vertical position, the length of the days and nights would be the same anywhere between the equator and the North or the South Pole. Yet, you know

that the days and nights do differ in length during the year. You know that the days in summer are long and the nights short, while in the winter the nights are long and the days short. What makes this difference? Study carefully Key Picture 14 and then explain the problem. With your apparatus demonstrate the causes of these variations.

4. Causes of Our Seasons

359. Causes of Our Seasons. — If you have given very careful thought to Key Picture 14, you must see that the days become longer little by little as the area of light moves up towards the north pole and the nights become shorter and shorter as the earth moves from the December to the June position. This is because the earth's axis is tipped at an angle of $23\frac{1}{2}°$ from the plane of the earth's orbit. But this tipping alone would not bring these differences in the length of day and night. What makes the days get longer little by little? It is evidently due to the movement or revolution of the earth about the sun. But remember that in this movement of the earth about the sun, the north pole always points in the same direction, — towards the Pole Star (Fig. 225). This makes it impossible for the days and nights to be equal except in the September and March positions. Explain again what makes it warmer in summer than in winter.

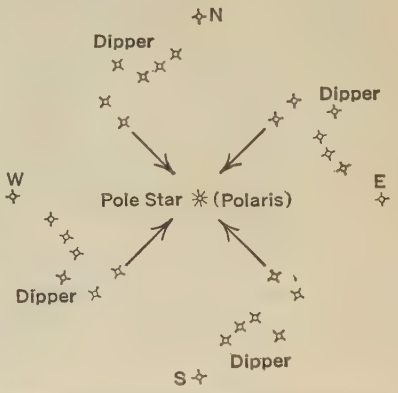


Figure 225. — The Pole Star and the Big Dipper.

How the Dipper appears to change its position during the year. The earth revolves about the sun with its axis always pointing towards Polaris.

(Key) Demonstration 39: ***Problem: What causes variations in the intensity of the heat and light rays of the sun during the year?***

Materials: A small globe; two thumb tacks; a pair of compasses; and a piece of cardboard of length about two feet and width equal to the radius of the globe.

Method: Draw lines the full length of the cardboard, one-eighth inch apart and parallel to the long side of the cardboard. These parallel lines represent the light rays which come from the sun to the earth. Spread the compasses so that the two points stand on the two corners of one *end* of the cardboard. Swing one of the points across the cardboard from its corner to the opposite side, thus marking a quarter circle. Cut out the quarter circle.

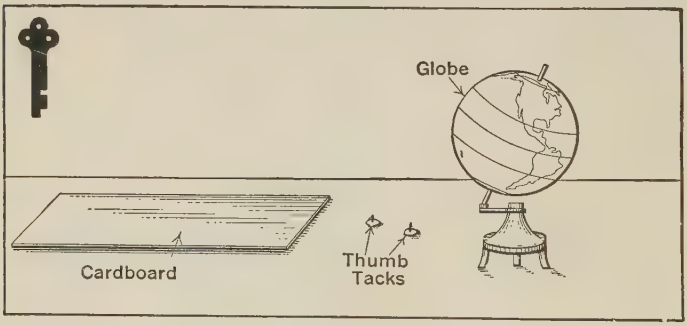


FIGURE 226. — (KEY) DEMONSTRATION 39.

Use this apparatus thoughtfully and try to understand each step before you take up the next one.

Put a thumb tack in the globe over New York and another thumb tack about two inches directly "north" on the globe. Stand the globe so that its North Pole points away from you; then rotate the globe on its axis so that the thumb tacks face you. You yourself now represent the sun, and New York is in the position of noon, December 21. Fit the curved end of the cardboard to the globe, so that the curved edge passes over the two thumb tacks and the lower edge of the cardboard is horizontal. Now count the lines on the cardboard which end on that part of the curve included between the thumb tacks.

Stand the globe so that its North Pole points *toward* you, and rotate the globe on its axis so that the thumb tacks face you. Once again you represent the sun, and New York is now in the position of noon, June 21. Fit the curved end of the cardboard to the globe,

so that the curved edge passes over the two thumb tacks and the lower edge of the cardboard is horizontal. Count the lines on the cardboard which end on that part of the curve included between the thumb tacks.

Observations: In the December position, how many "rays" from the sun struck the region between the two thumb tacks? In the June position, how many "rays" struck the same region? Explain why New York is warmer in June than in December.

Explain what our days and years would be like if the earth's axis were vertical; if our North Pole did not always point in the same direction; if the earth did not revolve around the sun; if the earth did not rotate on its axis.

Conclusion: What causes variations in the intensity of the heat and light rays of the sun during the year? Give four causes based upon this demonstration.

Practical Applications: How could one arrange to enjoy summer all the year round at an even temperature without going into the torrid zone? Why does the sun never set for six months of the year in the region around the North Pole? This is a difficult demonstration. Give a full account of it, together with careful drawings, in your Science Discovery Book.

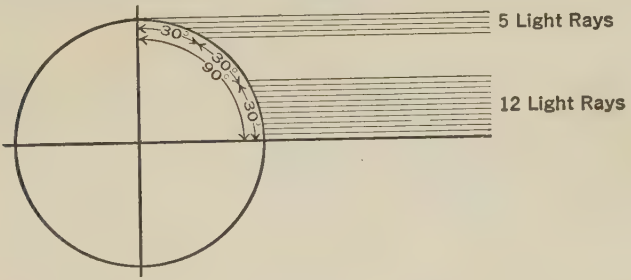


FIGURE 227. — ONE IMPORTANT CAUSE OF THE SEASONS.
Be sure that you understand this picture.

360. The Seasons. — Your study has now shown you why we have (1) day and night, (2) a difference in the length of day and night, (3) a warm and cold period during the year, (4) two periods when the temperature is neither high nor low, and (5) periods at the poles when it is light or dark for at least six months. These conditions are all due to differences in the position of the earth in its relation to the

sun. A little thought will show you that these changes or differences in heat intensity, called the seasons, are due to four distinct causes, as the earth passes through space at the rate of 1102.8 miles a minute in its path about the sun. Study Key Picture 14 once more and explain fully the four causes of the seasons.

361. Importance of the Seasons. — It was a wise provision of Nature that she should tilt the earth at a slight angle. To realize what would have happened on the earth without this tilting, it is but necessary to place the globe used in your

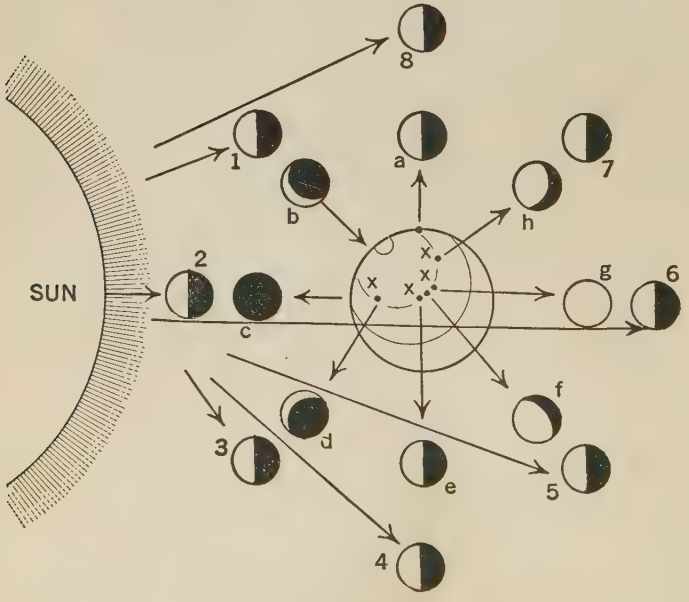


FIGURE 228. — THE PHASES OF THE MOON.

1 to **8**, the moon as it would appear to one standing on the sun during the month. **a** to **h**, the moon as it appears to us during the month. **x**, **x**, **x**, **x** indicate Washington, D. C. Note that each night, as **x** moves past the moon, it has advanced towards a new position. This causes the moon to rise later every night. Explain. Why cannot the moon be seen at all times during the month? What makes a full moon?

experiments in a vertical position and then think out the results of this position. All parts of the earth would have different kinds of season, but each would have the same season forever. Now think of all the effects of this condition upon plants, animals, man, occupations, and industry. Explain to your class.

FIGURE 229. — LOW AND HIGH TIDES.

Note the boats in the two pictures. The upper one was photographed at 10 A.M. and the lower one at 5 P.M. What differences do you notice? Account for them? What causes the tides? How did the extra boat get in the lower picture?

5. THE MOON AND TIDES

362. Tides. — At certain intervals which vary on succeeding days the waters of the ocean begin to rise on the shore and then, after about six hours, begin to recede again. These movements of the ocean water we call the *tides*. The moon and sun attract the earth with a force just great enough to move the water of the ocean. Why does not the soil visibly move? Explain this. The water thus tends to follow the moon and the sun about until it strikes a shore. It is

held there, and then recedes when the influence of either body is past for the time being. Twice each day, then, the tides rise, at intervals of about 12 hours and 25 minutes (Fig. 229).

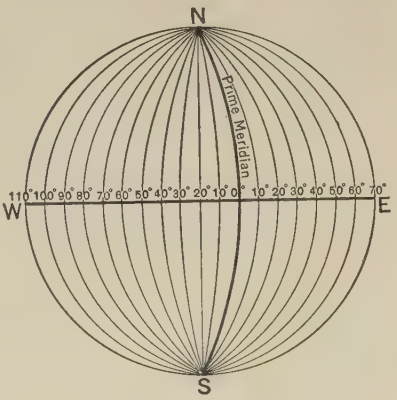
You may well ask: Of what value are the tides? Many answers may be given. (1) The tides keep the water in bays and estuaries in motion, preventing it from becoming stagnant and dangerous to health. (2) High tides make it possible for ships to enter shallow harbors such as that of Antwerp, Holland. (3) Tides are impounded behind dams as they come in and then used to run water wheels and machinery. The corn to feed General Howe's army while it was encamped on Staten Island during the Revolutionary War was ground by a grist mill run by the tides. How did the moon feed Howe's army? (4) The ebb tides provide opportunity for shell-fishermen to furnish many of us with food. Explain. (5) Tides have been used to run machinery through the rising and falling of buoys.

Tides are sometimes dangerous, however. Where they rise they obscure dangerous rocks. In other places they cause eddies and whirlpools, which make navigation a hazard. Hell Gate, New York City, is a good example of a dangerous whirlpool caused by the tides.

6. How Location, Distance, and Direction Are Determined

363. Direction on Our Earth. — For thousands of years the ancients believed our earth to be flat, but Aristotle, the great Greek philosopher (fĭ-lŏs′ō-fẽr), noticed that the moon was covered by a curved shadow when it was eclipsed (ĕ-klĭpst′) by the earth and that ships, as they went to sea, disappeared below the horizon. Columbus's crews revolted on board ship in his first American voyage of discovery because they believed that the ships would drop off the edge of the world. Copernicus (kŏ-pûr′nĭ-kŭs), the great Polish scientist, in 1530 first declared that the world was round and that it rotated on its axis.

Our directions depend on the sun. We call the *dawn* point or the direction towards the rising sun *east;* the opposite direction we call *west.* If you stand with your right hand pointing east and your left hand pointing west, you are always facing towards the north pole or *north.* The opposite direction will be *south.* By *down* is meant *towards the center* of the earth; by *up* is meant *out into space.*



364. Latitude and Longitude. — You know that the earth rotates once upon its axis in 24 hours. Circles are divided into 360 parts or degrees for convenience in measuring, and since the earth at the equator is circular, we divide the equator into 360 parts or degrees. At any interval above or below the equator the circle of the earth is also divided into the same number of degrees, but the space on the earth's surface covered by each degree is smaller as one goes north or south. Explain. At every degree north or south of the equator an imaginary line is drawn on the earth called a *parallel of*

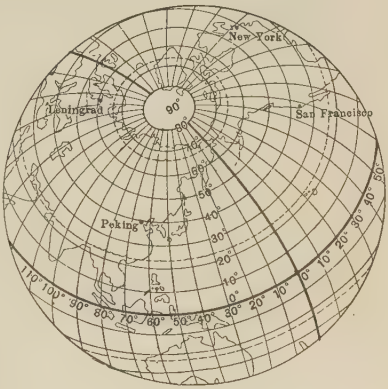


FIGURE 230. — LONGITUDE AND LATITUDE.

How many degrees of each are there on the earth? Find the latitude and longitude of each city indicated here. If one kept going west would he gain or lose time? Explain.

latitude. Latitude, then, is any distance on the surface of the earth north or south of the equator. How many parallels of latitude will there be between the equator and the north or south pole?

Likewise, through every degree on the equator an imaginary line is drawn reaching from the north to the south pole. Such lines are called *meridians.* How many are there on the earth? These meridians indicate the *degrees of longitude. Longitude, then, is any distance on the equator or on any parallel east or west of any given meridian.*

For convenience, all nations have agreed upon the meridian of Greenwich (grĕn'ĭch), England as the *prime* meridian. It is marked 0. From this line the meridians are numbered in both directions from 0 to 180, where they meet on the opposite side of the earth (Fig. 230). A person standing on the Greenwich meridian at the equator would be in Latitude 0° and Longitude 0°. Explain. Thus the whole surface of the earth is marked off in such a way that it is possible to tell just where any city or spot is on its surface. To secure greater accuracy each degree is divided into 60 *minutes,* indicated by the sign ′, while each minute is again divided into 60 parts called *seconds,* indicated by the sign ″.

Since a degree will cover $\frac{1}{360}$ of 24,902 miles, the circumference of the earth at the equator, the distance in miles of a degree at the equator is about 69; of a minute is 1.15 miles; of a second is .19 of a mile. It is possible, therefore, to locate a ship within a few rods of the exact spot anywhere on the earth. As we go nearer the poles it is possible to locate a spot with even greater exactness. Why?

7. Time: How Determined and How Used

365. The Meaning and Importance of Time. — We reckon time on the basis of the earth's movements. Its rotation about its axis gives us our *day* (and night); its revolution (journey) about the sun gives us our *year.*

The *solar* day (sun time) is reckoned from *noon* to noon. For any one place, 12 m. (noon) solar time means that the meridian of that place is *directly* under the sun at that moment. Twenty-four hours must pass before it can again occupy the same position. Our *civil* (legal) day, though it begins at 12 midnight instead of 12 noon and though it is measured by Standard time (see next section) rather than by

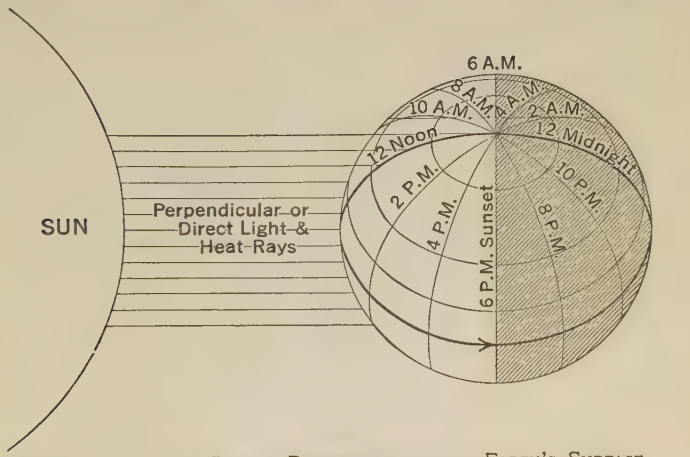


FIGURE 231. — HOW TIME IS DETERMINED ON THE EARTH'S SURFACE.

Note the way the earth is turning. If it is noon at Washington, D. C., will it be morning or afternoon at San Francisco? Explain. Allowing a difference of 5 hours between London and New York, what time will it be in London when it is noon in New York? Work out other problems for yourself in this picture.

solar time, after all depends upon solar time. Perhaps you can tell why, if you ask yourself how we know when it is midnight.

The division of the day into hours, minutes, and seconds has an interesting explanation. Investigate and report to the class.

Our year is the time consumed by the earth in making one trip around the sun. It contains $365\frac{1}{4}$ days. This fraction is taken up in our calendar by the addition of one day to

every fourth year, Leap Year. The years, we know, are dated with reference to the life of Christ. An event A.D. 1914 really occurred, then, during the 1915th revolution of the earth about the sun, reckoned from the time of Christ's birth.

Report to the class on " month " and " week."

366. Standard Time. — Because of the confusion in transportation resulting from the use of local time, in 1883 the Government adopted Standard Time. Across the United

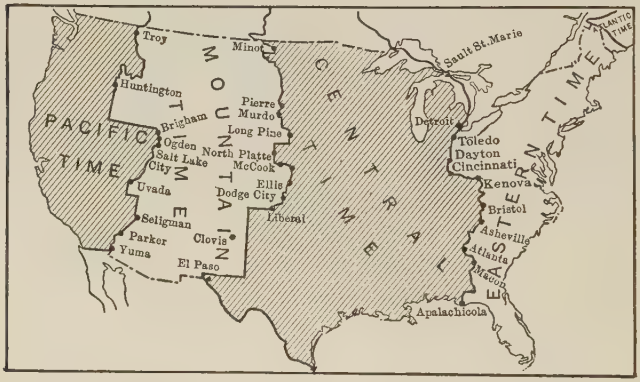


FIGURE 232A. — STANDARD TIME ZONES.

Why are these zone boundaries so irregular? What is the advantage of a time zone?

States certain meridians 15° apart were set aside as centers of time belts, the 75th meridian being adopted as the center of the Eastern Time belt; the 90th for the Central Time belt; the 105th for the Mountain Time belt, and the 120th for the Pacific Time belt (Fig. 232a). Each belt covers one hour of time and within each belt all clocks are timed to the time of the central meridian of that belt. But when the border of the belt is reached, the watches are set back one hour if one is traveling west, and forward one hour, if traveling east. Explain. How many times would one reset his watch in going from New York to San Francisco?

367. International Date Line. — If one begins to go west from New York, he will keep setting his watch back, as he goes along, until he has gone halfway about the earth or covered 180° of longitude or 12 hours of time. He has really gained this amount of time. To simplify this difficulty of determining the exact time, and especially the day of the week, an International Date Line was established in the Pacific Ocean, which follows in general the 180° meridian. Study carefully Figure 232b and answer the questions upon it.

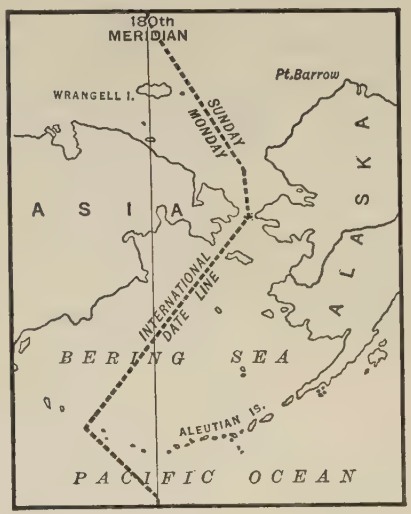


FIGURE 232B. — THE INTERNATIONAL DATE LINE

In going west one drops one day when crossing this line. That is, Sunday is changed to Monday. Can you see why? What would happen if one went east? Why is this line so irregular? Explain.

368. Time and the Work of the World. — Your study of the solar system has shown you that it runs on a schedule. It never varies. Because of this men worked out a system of timing their actions by the sun. To-day time is indispensable in carrying on our work. If you plan a picnic for a certain date, you are really dependent on the sun for fixing the time. If you go to a lecture, you plan to be there on time. If you pass to your recitations at the ringing of a bell at 10.15 A.M., you use the sun to guide you. Railroads arrange their schedules by the sun. Business is transacted by the sun. You are early or late according to a time schedule based on the sun's path. You live by time, you remember by time, you plan by time. Time is absolutely necessary to carry on the world's work.

A NEW TEST FOR YOUNG SCIENTISTS

The Review Outline following each of the first thirteen chapters of this book was prepared to help you sum up and review your work in that chapter.

You have now become familiar enough with the plan of these Review Outlines to construct your own. For each of the remaining chapters, under the guidance of your teacher and using the chapter Summary as a basis of your work, carefully construct in your Science Discovery Book a Review Outline. This will be a new and thorough test of your ability as a young scientist. You will be surprised to discover how much you have progressed since you began your study of Chapter I.

SUMMARY

No *work* is done on our earth without the *direct help* of the *sun.* Its influence can be traced in all great industries such as *transportation, manufacturing, power generation,* etc.

The tremendous *attractive power* of the sun is due to its great *mass,* which keeps *eight planets* revolving in their orbits at various distances from it, all *differing* in *size, composition,* and *weight.*

From the surface of our earth can be seen thousands of other suns called *stars,* all of which are probably the centers of other *solar systems* much larger than our own and all situated at unthinkable distances from our earth. Many of these stars happen to be grouped in such a way as to form *constellations* which have been given appropriate names. Other groups are so far away as to form an indistinct white band across the sky called the *Milky Way.*

Our earth moves in a regular *orbit* about the sun once in $365\frac{1}{4}$ days at a speed of *18.5 miles a second.* It *rotates* completely about its axis once every 24 hours, causing day and night. By the *inclination* of its axis at an angle of $23\frac{1}{2}°$, a difference in the lengths of day and night is brought about. A variation in the lengths of day and night during the year is caused by the *revolution* of the earth about the sun.

The seasons have a profound effect upon our habits, our cloth-

ing, our food, our animals, our plants, our methods of traveling, and our industries.

Our earth is lighted at night, during a part of every month, by sunlight reflected from the *moon*, which *revolves* about the earth once every *27½ days*, making one complete rotation about its axis during the same period of time. The attraction of the moon and sun for the earth pulls the waters of our oceans out of place, causing the *tides*.

Our earth's shape, its revolution about the sun, and its rotation on its axis give us ideas of *time* expressed in *years*, *months*, *days*, *hours*, *minutes*, and *seconds*. *Degree lines* marked off on the surface of the earth give us *latitude parallels* and *longitude meridians*, by means of which we can locate any spot on the earth's surface with great definiteness, tell what time it is at this spot and what time it is at any point on the earth where we happen to be. To keep accurate time in a large country such as the United States, *Standard Time belts* have been adopted. To aid round-the-world travelers an *International Date Line* has been established.

Without a *time schedule* no efficient work would be possible. *Time* is an *essential factor* in all *industries* and in all *business affairs*. It is safe to say that we run our world by the sun.

Remember that :

1. The sun is the source of all energy.
2. The sun can do many kinds of work.
3. The sun is the center of our solar system and controls the movements of all the bodies in this system.
4. All the phenomena of eclipses, tides, etc., are caused by the different relative positions of the sun, earth, and moon.
5. Direction and time on the earth are based upon the relation of the sun to the earth.

THOUGHT QUESTIONS

1. How do we know that the sun does not revolve about the earth?
2. Mr. A travels two degrees eastward on the equator, while Mr. B. travels two degrees eastward from Brooklyn, New York. Which has the farther to go? Explain.
3. Explain why it never becomes dark in northern Lapland for six months of the year. What conditions prevail during the next six months? Explain.
4. Explain why the days and nights are of equal length in September and March.

5. Every place on the whole earth has equal length of days and nights in September and March. Explain.

6. Quito, the capital of Ecuador, has equal days and nights the whole year through. Explain how this can be so.

7. Why is it hot in Buenos Aires in December?

8. As one goes towards the north pole in summer the days are constantly increasing in length. Explain.

9. Could the sun get between the moon and the earth? Explain.

10. What occurs when the moon gets between the sun and the earth? (Figs. 233a and 233b.)

Popular Science Monthly.

FIGURE 233A. — THE MOON BLOTTING OUT THE SUN.

This photograph was made during the eclipse which occurred on January 24, 1925.

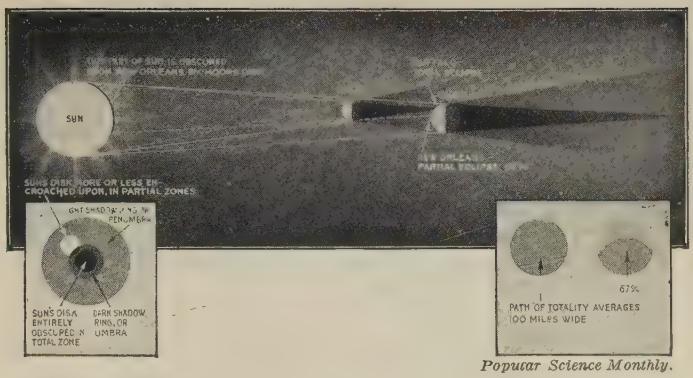
11. What occurs when the earth gets between the moon and the sun? Explain.

12. What would happen if the earth did not rotate?

13. What would happen if the earth did not revolve about the sun?

14. What would happen if the earth ceased both its revolutions and rotations?

15. What would happen if it ceased its revolutions but continued its rotations with its axis perpendicular to the plane of its present orbit?



Popular Science Monthly.

FIGURE 233B. — THE ECLIPSE OF THE SUN, JANUARY 24, 1925.

Find the umbra and the penumbra. Why was the path of darkness on the earth so narrow? Why was the eclipse visible only north of the equator? When could a lunar eclipse occur? Explain.

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Chambers. The Story of Eclipses. D. Appleton and Co.
Chambers. The Story of the Solar System. D. Appleton and Co.
Collins. The Boy Astronomer. Lothrop, Lee, and Shepard Co.
Fabre. This Earth of Ours. Century Co.
Griffith. The Stars and Their Stories. Henry Holt and Co.
Johnson. Sky Movies. The Macmillan Co.
Lewis. Astronomy for Young Folks. Duffield.
Luckiesh. Book of the Sky. E. P. Dutton and Co.

Popular Science Monthly.

KEY PICTURE 15. — WEATHER AND CLIMATIC CONDITIONS IN THE UNITED STATES.

Note the general storm paths across the country. Where do the storms begin? Where do they go? Study this map until you know what kind of air conditions is found in each section. This will help you in the study of this chapter.

CHAPTER XV

THE RELATION OF SOLAR ENERGY TO THE WEATHER

I am Storm — The King!
My troops are the wind and the hail and the rain,
My foes are the woods and the feathery grain,
The mail-clad oak
That gnarls his front to my charge and shock.
— Francis M. Finch.

"When the robin sings loudly we shall have rain." Do you believe in this sign? What are weather signs? Name some. Did you ever have the weather spoil a good time on which you had planned? What do you suppose makes up the weather? Do rain, wind, snow, temperature, and sunshine have anything to do with it? Did you ever look at a weather map? Did it mean anything to you? If you learned to read a weather map, you would probably become much interested in the weather. Who forecasts the weather for us in the newspapers? Did you ever hear of climate? of tornadoes? Of course you know what a thunderstorm is! But what makes these things happen? All these things and many others will be made plain in this chapter.

Some Practical Questions :

1. Why do clothes usually dry better on warm than on cold days? on windy days than on calm, still days?
2. Why do water pitchers "sweat" on warm, "muggy" days?
3. Why does frost often form on window-panes in cold weather?
4. Why does a very heavy dew generally mean fair weather?
5. Why are people tired and uncomfortable on a "muggy" day in summer?

Home Problem. — Make a wind vane and a windmill. Set them up and make them work. Determine one practical use of each.

Field Problem. — If the wind is in the east, note what it brings. If a rain storm, note the wind direction after the storm has passed. Account for any change. What makes it clear up? Study Figure 247 before making your final decision.

1. Weather Signs

369. The Weather. — No one topic of conversation is more common than that of the weather. "It's a fine day," "Is it going to rain?" and "What do you think of this kind of weather?" are expressions that indicate the importance of the weather to the average person.

The weather indirectly determines the amount and quality of the work done by the farmer in his field, the grocer in his store, the banker in his office, or the laborer in his factory. Why is this so? It is essential, therefore, that you study the weather in its vital relation to the life and work of the community.

370. Weather Signs. — Many people say that if the tea kettle boils dry, it is a sure sign of an approaching storm. This may or may not be true. Therefore, it cannot be laid down as a rule. "If one's bones ache, it is going to rain." The ache may be due to another cause. The weather may have something to do with the ache, but it is not a true sign. Again, "if it rains on St. Swithin's day, it will rain every day for six weeks following." This is a pure superstition.

Some signs, however, are more likely to be true than others. A few such follow:

(1) "Mackerel sky and mare's tails,
Make lofty ships carry low sails."

(2) "If the sun goes pale to bed,
'Twill rain to-morrow, it is said."

(3) "Evening red and morning gray
Cheer the traveler on his way."

Make a collection of such sayings about the weather.

2. Factors Which Make Weather

371. Weather Factors. — When you ask: What makes it rain? Why is there a heavy dew this morning? Is it going to be a fine day to-day? — you little think of how many factors enter into the kind of day you finally experience. What are some of these factors and how do they act? Temperature is one of them.

(Key) **Demonstration 40:** ***Problem: How does a thermometer show changes in temperature and how may we know if the thermometer is giving us the exact condition of the air?***

Materials: Two beakers; an iron tripod; a Bunsen burner or alcohol lamp; cracked ice; water; a Fahrenheit thermometer; colored ink; an Erlenmeyer flask; a rubber one-holed stopper; and glass tubing (to fit stopper) about six inches long (Fig. 234).

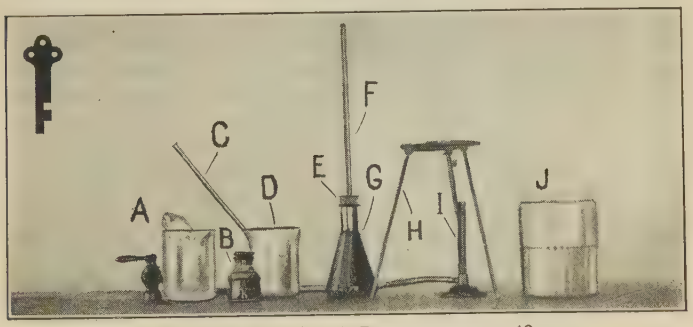


Figure 234. — (Key) Demonstration 40.

A, beaker of cracked ice; **B**, red ink; **C**, thermometer; **D**, beaker; **E**, one-holed stopper; **F**, glass tubing; **G**, Erlenmeyer flask; **H**, tripod; **I**, Bunsen burner; **J**, jar of water.

Method: A. Fill the flask full of water. Put in a small amount of red ink, shake to mix, and fit stopper and tubing into flask so that colored water rises about one-third of distance to top of tube. Now mark this point and hold the flask over the Bunsen flame for a few moments. Note what happens to the column of water, and basing your observations upon previous work on heat, explain.

B. Put some cracked ice in one of the beakers. Set the bulb of the thermometer against this ice after recording the reading of the thermometer and observe what happens. Next heat some

water in the other beaker until it boils. Then recording the reading of the thermometer in the ice, place the bulb in the boiling water and observe what happens. What is happening to the mercury in the thermometer bulb? Why does it rise or fall? Give reasons for your answer.

C. Fill the beaker containing ice full of ice and bury the bulb of the thermometer in this ice. Keep it there until the mercury column stops falling. Read where it stops falling. What is the mark there? Is the thermometer correct? Is its scale correct? Now place the thermometer in the beaker containing the hot water and bring the water to a boil again. Note the highest reading of the thermometer. Is it correct? What is the sign on the thermometer at this point?

Observations: Write out fully all that you saw occur in this three-part demonstration and fully explain each step.

Conclusions: What are your conclusions? Can you prove them to be correct? Explain.

Practical Applications: How could you make a thermometer and test it out? Try it. Tell the above story complete in your Science Discovery Book. How does the mercury in a thermometer rise and fall as it hangs on the side of your house or on the wall of one of the rooms of your home? The heated air coming into contact with the bulb of the thermometer causes the mercury in the bulb to expand. It then rises in the tube. The reading on the scale is simply a scheme of man to indicate a difference in temperature. You feel warm, then, on a warm day because the air about you is warm and it is warm air that makes the thermometer rise.

372. Air Pressure. — You know that differences in altitude make differences in air pressure. But are there any other factors which affect air pressure? What makes heated air rise? Is the weight of hot air the same as the weight of the same volume of cold air? Test this for yourself.

Suggested Experiment. — Procure a horn balance, a Bunsen burner or alcohol lamp, two flasks of equal size, some fine sand, and a piece of string. Balance the two flasks on the balance. If they do not exactly balance, they can be made to do so by dropping a few grains of the sand into the one which hangs higher. Now apply the flame gently to the shoulder of one of the flasks. Watch results. What is in the flasks to begin with? How do you know this? Why apply the heat to the shoulder of the flask? Why exactly balance the two flasks? What happened? What made

one flask rise? Which flask fell? What happened to the air in this flask? What is the effect of heat on air? Why does heated air rise?

373. Air Pressure and the Barometer. — Temperature of the air, then, will have something to do with its pressure, since the lighter a volume of air the less pressure it will exert upon a surface. Now suppose that warm air or cold air or moist air comes into contact with the bulb of a barometer which also contains mercury. What will happen?

FIGURE 235. — (KEY) DEMONSTRATION 41.

(Key) Demonstration 41: ***Problem: What is the effect of atmospheric pressure upon a barometer?***

Materials: Rubber tubing (**A**); a ring stand (**B**); a boiling tube (**C**), 1″ × 8″; a barometer tube; a two-hole stopper to fit boiling tube; bent glass tubing; and 2 pounds of mercury (**D**).

Method: Fill the barometer tube with mercury and place over it the inverted boiling tube. Keeping this relation of the two tubes, reverse their positions and clamp the boiling tube to the ring stand. Fit the rubber tubing to the glass tubing and insert the free end of the latter into a hole of the stopper. Fit the other hole of the stopper to the barometer tube and slide the stopper down firmly into the mouth of the boiling tube (Fig. 235).

Now placing the free end of the rubber tubing in the mouth, draw in the breath as hard as you can. Watch the mercury. When it is as low in the tube as you can bring it, place a finger and thumb on the rubber tubing, hold it tightly, and remove the tube from mouth.

Now watch the column of mercury and let go of the rubber tubing. What happens?

Observations: Describe all the things that happen in the experiment. Do you think that the mercury column ever naturally varies in height? If so, when?

Conclusion: Does atmospheric pressure affect a barometer? How is this brought about? Explain fully.

Practical Applications: When air rises, it is warm and the pressure is low. Storms are due to the rapid rising of air. How does a barometer predict a storm or fair weather? Do not fail to make a complete record of the above demonstration in your Science Discovery Book.

374. Humidity. — You have noticed the water in the air when it is foggy, when it rains or snows, or when sleet is coming down. But there is water vapor in the air at all times and this is invisible. The term *humidity* is given to invisible water in the air. The amount of such vapor in the air at any one time can be determined.

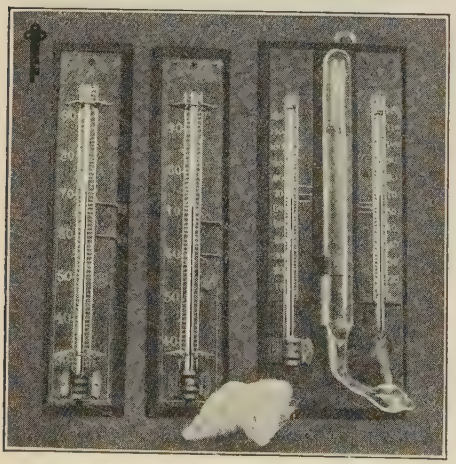


FIGURE 236. — (KEY) DEMONSTRATION 42.

Study the scales on these instruments and become familiar with them as you work the demonstration.

(Key) Demonstration 42: ***Problem: How is the relative amount of water in the air determined by the use of a hygrometer?***

Materials: A wet- and dry-bulb thermometer apparatus (hygrometer) (Fig. 236) or two Fahrenheit thermometers; a small piece of muslin; thread; and some water.

Method: A. In using the hygrometer simply fill the water cup with clean water and then fan the wet bulb for a few moments. In using the two Fahrenheit thermometers wrap a small piece of muslin about the bulb of one thermometer and tie it with the thread. Wet the muslin.

B. At the beginning of the demonstration take the readings of

both thermometers. Do so again after fanning the wet bulb for a few moments. Be sure that it has fallen to its lowest point. Now record the dry-bulb reading. Subtract the wet-bulb reading from this and find the difference.

Dry-bulb reading —— degrees
Wet-bulb reading —— degrees
Difference degrees

C. Now consult the Relative Humidity Table (page 458) and follow its instructions.

Observations: What effect did the fan have on the water in the muslin? The water in the muslin may be compared with the water in the air. As it is evaporated by the wind caused by the fan it takes heat with it and lowers the temperature of the air about the bulb. What will determine the amount of evaporation from the bulb as it is set outdoors? Will wind have anything to do with it? If there is much water in the air, will the water evaporate fast? Explain. When will it evaporate fastest? Will the temperature of the air in any way affect the evaporation? The more the evaporation the more the mercury falls in the wet tube; the greater the difference in the readings, the lower the humidity. Is this statement right or wrong? Explain fully.

Conclusion: Explain fully, giving your proofs, just how a hygrometer tells us the relative amount of water in the air.

Practical Applications: If there is a high relative humidity, what does it mean? What does a low relative humidity mean? How may this affect human affairs? Is the relative humidity the actual amount of water in the air? Would this amount be stated in grams or in percentage? If the relative humidity figure is 50, the air contains just half as much water as it can possibly hold. We call the relative humidity here 50%. If it should read 75%, the air would be holding three-fourths of its total capacity. If the number should be 100 it would mean that the air was saturated with water, — it would have reached the *saturation* point and could hold no more. Here is good material for your Science Discovery Book. Write it out in full.

The Table of Relative Humidity, at the top of page 458, is used as follows:

For example, suppose that the dry-bulb thermometer registers 72 degrees while the wet-bulb thermometer registers 63 degrees. The difference between the two readings will be 9 degrees. Select the column having the figure 9 at its top and run the finger down it

TABLE OF RELATIVE HUMIDITY

DIFFERENCE IN DEGREES BETWEEN DRY- AND WET-BULB THERMOMETERS

DRY BULB	PERCENTAGE OF RELATIVE HUMIDITY														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
50	93	87	81	74	68	62	56	50	44	39	33	28	22	17	12
52	94	88	81	75	69	63	58	52	46	41	36	39	25	20	15
54	94	88	82	76	70	65	59	54	48	43	38	33	28	23	18
56	94	88	82	77	71	66	61	55	50	45	40	35	31	26	21
58	94	89	83	77	72	67	62	57	52	47	42	38	33	28	24
60	94	89	83	78	73	68	63	58	53	49	44	40	35	51	24
62	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44

until you find the number exactly opposite the dry-bulb reading. This number will be found to be 61%. This is the *relative humidity*. Read the two thermometers for several days and determine the relative humidity each day until you become expert in finding it. Remember that the indoors condition to be healthy should always read above 50 on the relative humidity scale. With a relative humidity above 50, the temperature of the room need not be higher than 68 degrees to be warm and comfortable.

375. Importance of Evaporation and Humidity to Life. — People who perspire freely are always cooler than those who do not, because the exuding water takes with it the heat from the body.

376. Humidity and Air Pressure. — In any one extended region where the air is concentrated, the air pressure is high and will be indicated by a high barometer. Under these conditions, evaporation of water will be retarded and the

humidity will be low. On the other hand, when the air pressure is low, evaporation will take place more rapidly and the humidity will increase. A continually falling barometer will therefore indicate cloudiness and approaching rain.

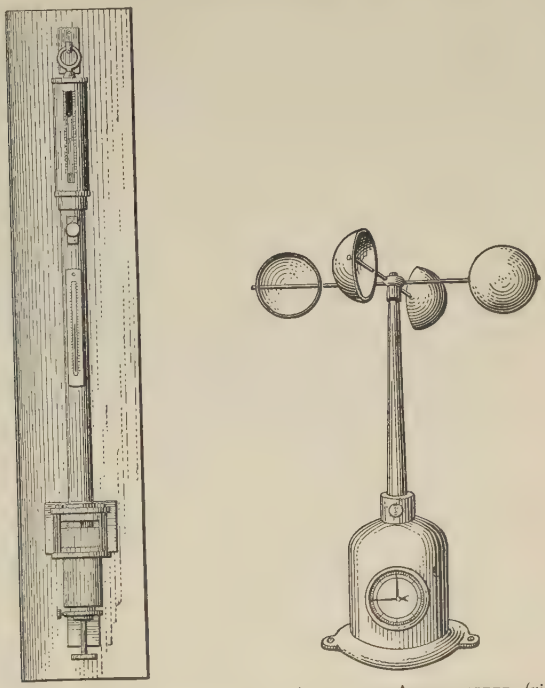


FIGURE 237. — A BAROMETER (left) AND AN ANEMOMETER (right).
One measures the atmospheric pressure; the other indicates the wind velocity. Is there any relation between the actions of the two devices? Explain.

377. Temperature, Air Pressure, and Humidity. — Where air expands due to a high temperature, evaporation takes place more rapidly. The pressure at that point will be reduced, due to the presence of lighter warm air and water vapor which is lighter than air. Humidity, then, generally accompanies warm weather. A great humidity will often accompany a temperature moderately high with no wind.

When these calms occur, "hot waves" result. The thermometer is not high, but suffering from heat is intense. Explain.

378. Air Currents. — Heated air expands. It is lighter than cold air (volume for volume). Explain. Moist air is lighter than dry air (volume for volume).[1] Why? The molecules of warm expanding air or moist air separate, thus making it relatively light. The surrounding heavier cold air rushes in and forces up the warm air. Air currents are thus set up

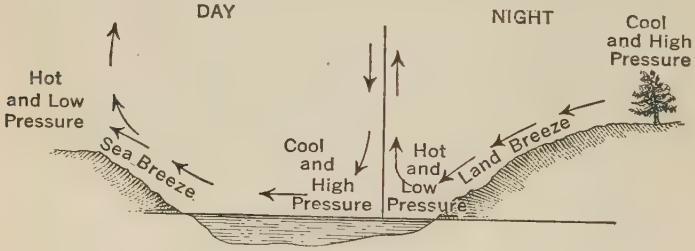


FIGURE 238. — DAY AND NIGHT AIR MOVEMENTS.
Study this picture and explain the direction of the arrows. Why should the wind blow landward during the day and seaward at night?

which we call *winds*. Winds at once increase evaporation from any surface over which they blow, since the dry air, as it rises, absorbs water and the next volume of dry air which follows takes its load also. It follows, then, that breezy days are cooler than still days, and muddy roads and wet clothes dry better on windy than upon quiet days. Explain. Will the air pressure be low or high on a windy day? What will the air pressure be on a quiet day? Try the Suggested

[1] The nitrogen and oxygen in the air are heavier than the water vapor. The more moisture there is in the air, the less oxygen and nitrogen there can be in any given volume because, as you have already learned, two bodies cannot occupy the same space at the same time. Therefore, the more moisture in the air, the less air pressure and the lighter will be any given volume of air. Can you see this?

Experiment on page 471 and from this tell what makes the wind blow.

379. Rate of Evaporation. — The rate of evaporation of water from the surface of the earth depends, then, upon (1) the amount of water vapor in the air; (2) the temperature of the air; (3) the air pressure; and (4) the air movements or wind. Given these factors which control the rate of evaporation, it is fairly easy to determine what the weather will be in the immediate future.

380. The Formation of Dew. — Now suppose you find out for yourself what happens when dew is formed.

FIGURE 239. — SNOW, DEW, AND FROST.

The snow crystals must have been formed in extremely cold air. Why? The rock marked 50° causes the formation of dew upon it. Why? The rock marked 22° has frost upon it. Why?

Suggested Experiment. — Get an empty varnish can of one-quart size, an iron tripod, and some ice. Fill the can two-thirds full of water and add enough ice to fill the can. Place it on the tripod. Watch for results. What do you note on the sides of the can after a few minutes? Could this moisture have come from within? Explain. Do you see moisture on the top? Lift the can and look at the bottom. Do you see moisture here? What caused the water to form on the can? This is dew. Does dew fall? Give a full reason for your answer. What makes the dew? Explain in full. Why do pipes containing cold water "sweat" in summer? Why can one see his breath out of doors in the winter time? Why will one's eyeglasses often become covered with mist when coming into a warm room from outside when the temperature outside is low?

381. Condensation. — When the temperature of the air is lowered, it is able to hold less water vapor. Explain. If the temperature of the air continues to become still lower, the moisture is forced out of the air, forming into

small drops of *rain*. This is *condensation*, which is the direct result of the rapid lowering of the temperature of a humid mass of air (Fig. 240).

382. Varying Results of Condensation. — *Dew* is formed when the condensation occurs on objects on the earth

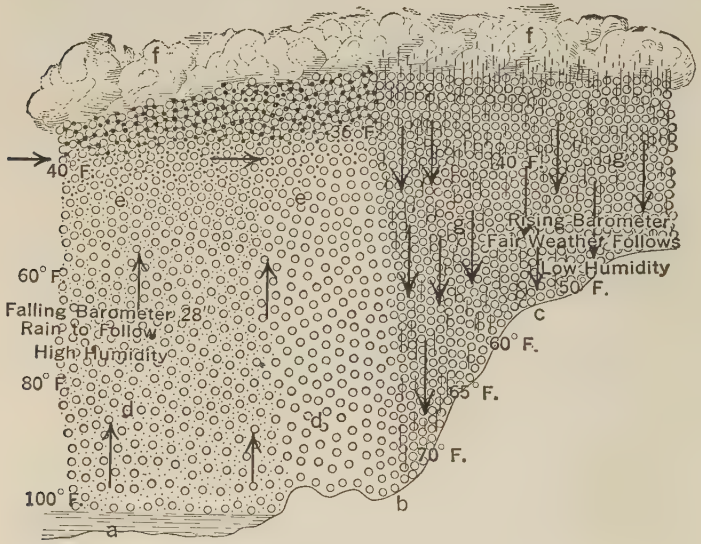


FIGURE 240. — STAGES IN CONDENSATION.

At **a**, the air is rising rapidly taking with it much moisture between its molecules. The barometer falls as the moisture increases. Why? The air temperature falls as the air rises. Why? At **e**, drops of water begin to form. At **f**, clouds appear and are carried to the right by the wind. Soon the moisture begins to fall as rain. Why? At **g**, the pressure increases. Why? The barometer begins to rise, the humidity is lowered, and fair weather follows at **b** and **c**. Why? This sums up the story of a rainstorm. Explain it fully.

(Fig 239). Explain. If the temperature at which condensation begins is below the freezing point, the moisture is condensed in solid form, as *frost* (Fig. 239). If the condensation occurs in masses of air near the earth, *fog* or *mist* appears. Fogs are common features of low lands near rivers

or lakes. Explain. If rain, falling from high altitudes, passes through an area of extreme coldness, the water drops may be frozen and fall as *hail*, causing damage and loss. At temperatures below the freezing point, the water vapor will form into most beautiful, six-pointed designs which we call *snow* (Fig. 239).

383. Clouds. — When condensation takes place above the earth, clouds are formed, greatly varying in character and

Taylor Instrument Co.

FIGURE 241A. — STRATO-CUMULUS CLOUDS.

These clouds are usually fair weather signs, but sometimes mass together and produce showers or thunder storms. Look for such clouds and see what they mean.

form. Clouds are interesting to us because of their beauty and their aid to us in predicting coming weather conditions. Study Figures 241a and 241b. Try to name the clouds you see and tell what they indicate.

3. RESULTS OF THE INTERACTION OF WEATHER FACTORS

384. What Is Weather? — You have been considering for some time the factors which produce weather. Air is

probably the most important of these factors. For example, to-day, it is hot and humid (that is, there is much moisture in the air), slowing up the evaporation of perspiration and making one uncomfortable; there is the slightest movement of the air and the barometer shows a low atmospheric pressure. To-morrow, the sun may be shining, the air moving at a gale,

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FIGURE 241B. — CIRRUS (sĭr′ŭs) CLOUDS.

Sometimes called "mares tails" and "bridal veil" clouds. They are the highest clouds and indicate the approach of stormy weather.

the temperature much reduced, and the air pressure greatly increased. What, then, is weather?

Weather is the general condition of the atmosphere, at any particular time and place.

385. Cause and Effect. — Weather changes are often so rapid and various that many people think that weather knows no law. It provides a beautiful day for a picnic or excursion

or the reaping of a harvest, or it may spoil all these activities and then do terrible damage besides. It may destroy crops by drought or floods. The weather is one of the best examples of the unerring working out of the *law of cause and effect.* For example, a rising barometer means fair weather, while a falling barometer means unsettled weather or rain. This shows that increased air pressure somehow causes fair

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FIGURE 242. — THUNDER HEADS.

Rapidly rising clouds near the earth with white tops and dark lower edges They indicate an approaching thunderstorm.

weather, while a reduced air pressure results in rain. There must be an intimate relation, then, between *air pressure* and the kind of weather we experience. This relation never varies.

386. Local Storms. — The most common of local disturbances are *thunderstorms.* In these, frictional electricity is generated by the extremely rapid condensation of water vapor, due to a very rapidly rising column of highly heated air

during an excessively hot day. Study Figures 243a and 243b and fully explain them.

The upper layers of air up to four miles high are charged with electricity, but it cannot reach the earth because of the dry layers of air below, which are poor conductors of electricity. As the clouds lower, the attraction between the earth and clouds becomes greater. There is a sudden increase in rainfall, due to greater condensation of moisture.

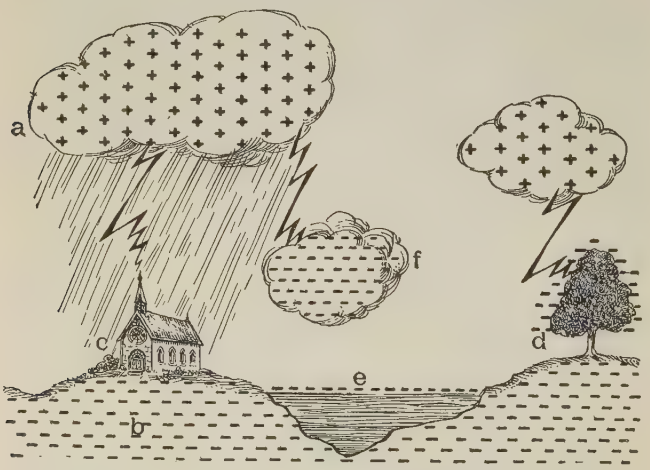

FIGURE 243A. — WHY LIGHTNING STRIKES THE EARTH.

The thunder cloud **a** is positively charged. The church **c**, resting on the earth **b**, which is negatively charged, acts as a conductor. The tree **d** is negatively charged as is also the water **e** and cloud **f**. The moist air acting as a conductor carries the charge from the positive to the negative point and the lightning strikes. What would prevent its striking the church?

The thunder is caused by the sudden contraction of the air, which was heated and rapidly expanded as the electric bolt passed through it. As the lightning flashes, other clouds may receive the electrical charge, or bodies of water, church steeples, towers, buildings, trees, steel structures, or persons may be struck. For this reason, during a thunderstorm it is best never to stand near a tree or a steel structure or in a

FIGURE 243B. — LIGHTNING STRIKING THE EIFFEL TOWER.

A picture presented to M. Camille Flammarion, the great French astronomer, by M. Eiffel, the builder of the tower. Taken at 9.20 P.M. What caused the lightning to strike the tower? What did Franklin discover about lightning? How could the lightning be kept away from the tower?

strong draft or to carry a metal object likely to attract the charge.[1] Every summer tells its story of the work of electricity in destroying lives and property (Key Picture 15).

We should not be afraid of thunderstorms, however, provided foolish risks are not taken. Rather, we should wonder at and admire the beauty and grandeur of an electrical storm as a fine example of the power of the elements and the working out of natural laws.

387. Tornadoes. — Tornadoes operate within a very limited area, sometimes attaining a speed of two hundred

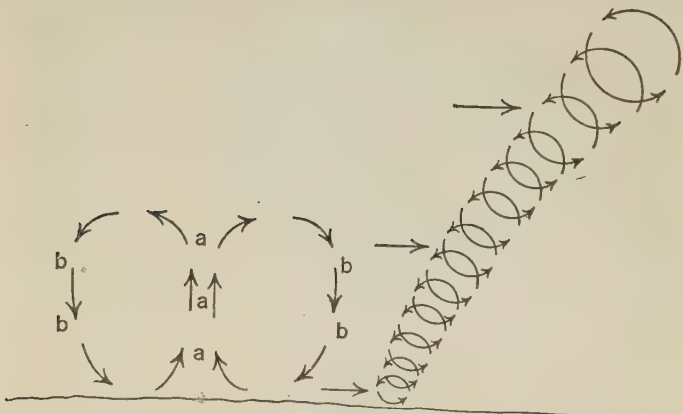

FIGURE 244. — HOW THE TORNADO WORKS.

What causes the air currents at **a** to rise and those at **b** to sink? This action soon develops a spiral action of the air shown at the right and the whole moves along at great speed.

miles an hour, their path seldom exceeding thirty miles in length and one fourth of a mile in width.

The marked conditions preceding a tornado are hot, humid days, south winds, and high cumulus clouds. These condi-

[1] It was Franklin who first discovered by his kite experiments that lightning is electricity of a frictional nature, and from his discovery he worked out the principle of the lightning rod, the points of which gradually receive the electrical charge during the storm. This prevents the sudden flash.

tions bring the tornado into action in the late afternoon or early evening. It is characterized by a rapid rotary motion produced by the meeting of several currents of air of different temperatures and by a very rapid rise in the temperature of the air near the earth. Study Figure 244 and answer the questions beneath it. What name is applied to tornadoes at sea? (Key Picture 15).

388. Importance of Rainfall. — Now imagine, for a moment, what would happen if all rainfall should cease. All rivers and streams would at once show a marked decrease in stream flow; the lakes would soon become shallow; the earth itself would lose its fertility and turn into a barren waste. Trees would lose their leaves, vegetables would dry up, and crops would not grow. All living things would be obliged to live along the sea coasts and even here life would eventually be at an end. Explain. Rainfall means life; life means industry and work.

389. Cyclones and Anticyclones. — The existence of areas of unequal pressure, extending from west to east across the United States, gives rise to what are called *storm areas.* These are areas where the cool air is rushing in from all sides towards a spot where the pressure is low, due to the rapid rising of warm air currents and the absorption of much moisture from the earth's surface (Fig. 245). But as these storm centers move eastward because of the rotation of the earth, they begin to revolve.

In the northern hemisphere great volumes of air revolve counter-clockwise and in the southern hemisphere they turn clockwise. Such whirlpools of air are called *cyclones.* Coming from the southwest, these cyclones bring seasons of drouth, called "hot waves," while those from the northwest and the lake regions bring seasons of unsettled weather and rain. Explain.

As the air rises over a cyclone area, it rapidly expands, cools, and spreads out, slowly sinking again perhaps hundreds of miles away, where it is gradually warmed again.

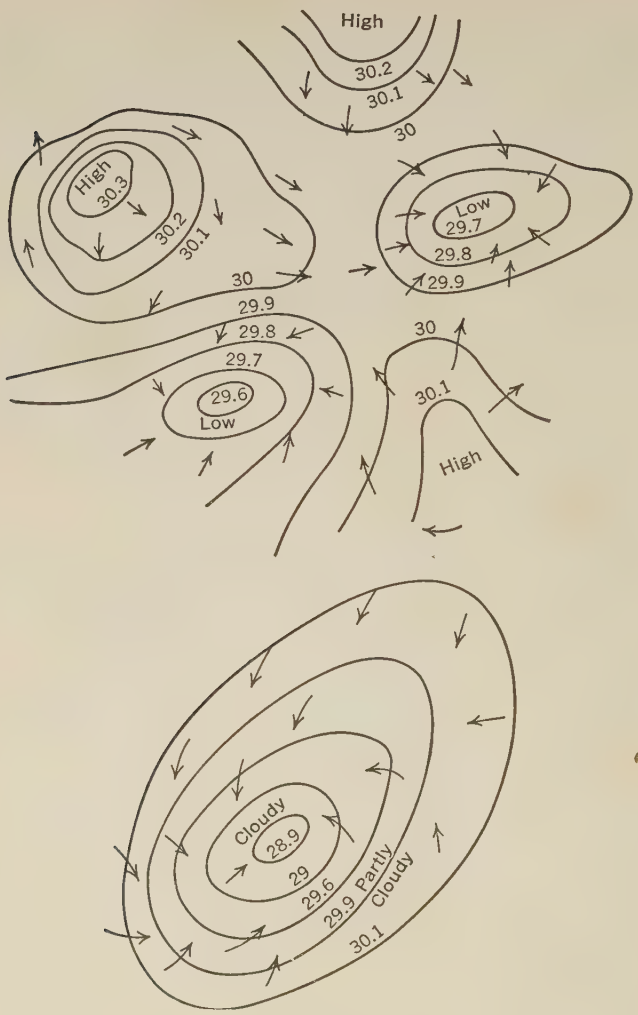

FIGURE 245. — HIGH AND LOW PRESSURE AREAS, — ANTICYCLONES AND CYCLONES.

Note the barometer readings on the different figures. Where is the cyclone? the anticyclone? Why do the high pressure arrows point to low pressure areas? Explain.

This movement of the cool air outward from the high pressure area is exactly opposite to that of the cyclone and is, therefore, called an *anticyclone*. This condition brings what we call a "cold wave." In areas of an anticyclone the air pressure is always high and the sky is clear. The winds are dry, cool, and gentle. Explain.

You can, if you desire, determine for yourself just how a storm center is formed.

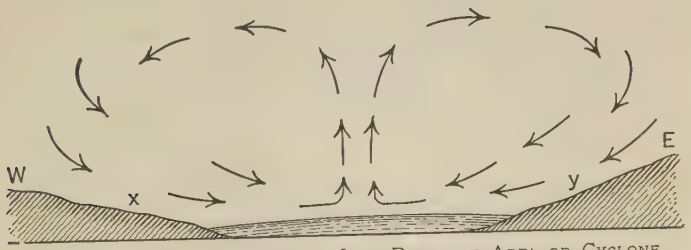

FIGURE 246. — THE CAUSE OF A LOW PRESSURE AREA OR CYCLONE.

Why does the air rise over the water? Why does it go towards the water at **y** and **x**? Where is the high pressure area? the low pressure area? Think of the center as the Mississippi River Basin and **E** as the Appalachian Mountains and **W** as the Rocky Mountains. Where will there be a cyclone? anticyclone? Why is the basin so hot in summer?

Suggested Experiment. — Secure a lamp chimney, a candle, several pencils, and two joss sticks. Light a small piece of candle (about one inch long). Place the chimney down over the candle, resting it upon the pencils so that it does not touch the table. Light the joss sticks. Hold one of them over the top of the chimney. Note direction of its smoke. Hold hand over the top of chimney. Note the heat. Now place the second lighted joss stick near the bottom of the chimney. Note the direction of its smoke. Move the stick entirely around the base of the chimney. Note results. What evidence have you that the air was rising from the chimney? What made it rise? In what direction was the air moving at the bottom of the chimney? How do you know? What caused it to move? From how many directions was the air moving towards the chimney? We may really call this heated area with rising warm air and inrushing volumes of cold air, a storm center. What are the conditions which cause a storm center? Give proofs.

390. Storm Paths in the United States. — A study of a storm path map of the United States (Key Picture 15) will show some interesting facts. (1) The general direction is east to northeast following the path of the prevailing westerly winds. (2) The storms originate in the northwest, southeast or south, but most come from the northwest. (3) The velocity of these storms is from 500 to 800 miles per day, the lower rate prevailing in summer and the higher in winter due to the marked differences in air pressure in the two seasons. (4) The changes in temperature as the storm center passes any given point are rapid and marked, being greater in winter than in summer. (5) The storm centers generally pass out over the Atlantic Ocean at or near the Gulf of St. Lawrence.

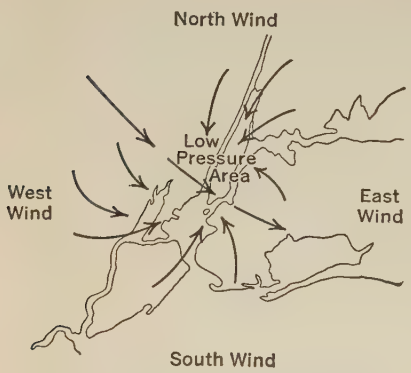

FIGURE 247. — THE EYE OF THE STORM.

In which general direction is the storm moving? Yet the wind's direction is continually shifting in New York City. Why? As the storm approaches the wind blows from the east; as it passes the wind blows from the west. Why does an east wind usually mean rain and a west wind mean fair weather? Explain fully.

4. CLIMATE AND ITS IMPORTANT EFFECTS

391. Climate. — You are now ready to learn the meaning of climate in contrast to weather. *Climate consists of the average of successive weather conditions at a particular place or in a particular area over a long period of time.* Climate, then, is a generalized statement of the weather. You may speak of the weather in New York City on any one day as being very variable or you may rightly use the same phrase

in referring to its climate through many years. The average temperature throughout the year is high, but the weather changes are sudden and extreme (Key Picture 15).

In Arizona there is a far different climate due to the dry air, little rainfall, and hot winds. Account for the climate in Oregon and central California (Fig. 248).

392. Climate and Plant Life. — It takes just the right combination of climatic factors to make a rich or a barren country. In Arizona, intense light and heat and lack of a plentiful water supply reduce plant life to a few forms.

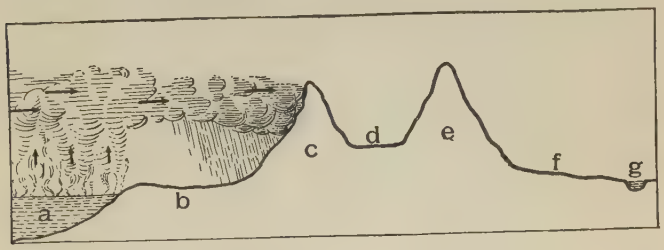

FIGURE 248. — MOUNTAINS AND RAINFALL.

Account for (1) rain clouds over **a**, (2) little rain at **b**, (3) much rain at left of **c**, (4) little or no rain at **d**, (5) drouths at **f** (Nebraska). **g** represents the Mississippi River. **c** shows the Sierra Nevada and **e** the Rocky Mountains.

On the other hand, the great warmth and moisture of the tropics give luxuriant plant growth, — enormous trees, lianas, broad-leaved plants of great size, and dense foliage.

In the temperate regions you find the great food plants — grains, grasses, orchard fruits, and vegetables. These feed the world. Here the amount of heat, light, and water is moderate and the soil generally good. The plants show no marked adaptations because there is no need of them.

393. Climate and Animals. — In the winter, most fur-bearing animals, like the rabbit, beaver, and fox, put on a thicker coat of fur. Others like the ptarmigan change color. Still others are permanently adapted to their surroundings like the polar bear in the Arctic regions, whose

fur is thick and white. Some animals such as the sheep will take on or shed their thick wool as they are moved to a cold or warm region.

Finally, great herds of cattle can be supported only in temperate climates. Why? Horses, cows, pigs, fowl, and other domestic animals can be cared for only where agriculture is widespread. Why is the United States the greatest meat-producing country in the world?

FIGURE 249. — THE SIAMESE TWINS.

Two giant Sequoia trees in the Tuolome Grove in California Climate and soil produced these monsters, — 300 feet high.

394. Climate and Industry. — The fruit-raising industry is a distinct and most important factor in the life of the people of California. Cotton growing, because of its seasonal nature, developed a peculiar type of workingman and a distinctive industry in the South. The open plains of the Northwest, due to the climatic conditions, encouraged the cattle-raising industry.

On the other hand, in the Torrid Zone little industry is

developed, owing to the excessive heat and humidity, though the natural resources are unlimited. Industry thrives best in the temperate countries, and the position of the United States makes it most fortunate in this respect (Fig. 250).

395. Climate and Occupations. — It is clear that carpenters, masons, architects, painters, railroad conductors, motormen, and a host of similar workmen will not be in

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FIGURE 250. — CLIMATE AND CIVILIZATION.

The greatest industries and the most energy are found among peoples living in the white zone. Explain why this is so.

much demand in Greenland or in the Sahara Desert. Likewise, where the climate is temperate and the natural resources many, the occupations will be many and different.

396. Climate and Health. — A humid, damp climate tends to cause throat and lung trouble. Dry climates, like that found in the southwestern states, help destroy bacterial germs in the lungs. High altitudes, such as are found in the Rocky Mountain region, are helpful to many people (Fig. 251). However, the most energetic people are those who live in changeable climates. A good example of such a climate is to be found in the region about New York City. Here the weather is changeable and the climate severe as compared to that found in the southern states, but the death rate is very low, about 10 in 1000 (Key Picture 15).

FIGURE 251. — THE YOSEMITE VALLEY, CALIFORNIA.

Said by many to be the most healthful and beautiful spot in the world. There is little industry here, but health-giving air and sunshine are free for all to enjoy. The elevation is more than 5000 feet.

SUMMARY

The *weather* is the result of the working of very fixed natural laws. The important factors composing weather are *air temperature*, *air pressure*, *humidity*, and *air movements*. Their constant action upon one another (humidity reducing evaporation and air pressure;

temperature reducing air pressure and increasing evaporation; the relations between air pressure, temperature, and wind, etc.) results in fair or foul weather, the latter showing as *precipitation* of moisture in the form of *rain*, *snow*, *hail*, or *fog*. The atmospheric conditions at any one time and place make up what we call *weather*.

Condensing moisture at a high elevation results in *clouds* of different kinds which may be precipitated as rain, snow, etc. Variations in rainfall at any one point are due to several air and land factors. The distribution of rainfall in the United States is fairly regular and of great importance to the people of the country.

The interaction of many weather factors over large areas develops *storm centers* called *cyclones* and *anticyclones*, which result in *high-* and *low-pressure areas* moving across the United States from the northwest to the southeast and northeast. Local storms may take the form of thunderstorms, tornadoes, etc., depending upon locality and peculiar atmospheric conditions.

The weather conditions over a large area and covering a long period of time make up what we know as *climate*. Climate has a profound effect upon soil, plant and animal life, crops, industry, occupations, distribution of population, and health. Weather exerts a tremendous influence upon the work of the whole world. But remember, — this is due to the sun's relation to our earth.

Remember that:

1. The weather is the result of the sun's action upon the factors of the environment and their reaction upon one another.
2. Precipitation (rain, snow, etc.) are the results of the action of the sun and of gravity upon moisture.
3. Storm centers are the result of the interaction of weather factors over a large area of the earth's surface.
4. Local storms are the result of the interaction of weather factors over a limited area of the earth's surface.
5. Climate is the result of the interaction of world environmental factors and deeply affects animals, plants, populations, and their occupations over the whole earth.

THOUGHT QUESTIONS

1. What causes low pressure and high pressure in the atmosphere?
2. Why do the lands along the seashore generally get rain in winter while the inland regions get snow at the same time?

3. Explain why at night there is usually a greater breeze on the water than on the land.

4. Explain why the wind blows from the east before a slow rain and from the west as the storm clears away.

5. Why do fruit growers on cloudy nights seldom fear damage to their fruits from frost?

6. Smoke from chimneys falls toward the ground when a storm is approaching. Why is this so?

7. Why does the temperature of the air drop after a storm?

8. Why does frost form on window-panes in winter?

9. Why will a balloonist have to throw out ballast as night comes on?

10. Why is our longest day seldom our hottest day?

11. How can different clouds in the sky travel in different directions at the same time?

12. Why does a fireplace smoke when a fire is just started, especially on a rainy day?

13. If a "low" is in Illinois, which way will the wind blow in Michigan? in Mississippi? in Kansas? in Ohio?

14. Why is there always much draft near a large fire?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Brooks. Why the Weather? Harcourt, Brace and Co.
Gilbert. Weather Bureau for Boys. Gilbert.
Houston. The Wonder Book of the Atmosphere. F. A. Stokes Co.
Humphries. Weather Proverbs and Paradoxes. Williams and Williams.
Huntington. Civilization and Climate. Yale University Press.
Jameson. The Weather. Taylor Instrument Co.
Jefferson. Man and Climate. Mark S. W. Jefferson. Ypsilanti, Mich.
Longstreth. Reading the Weather. The Macmillan Co.
Luckiesh. The Book of the Sky. E. P. Dutton and Co.

PART V

THE STORAGE AND USE OF SOLAR ENERGY BY LIVING THINGS

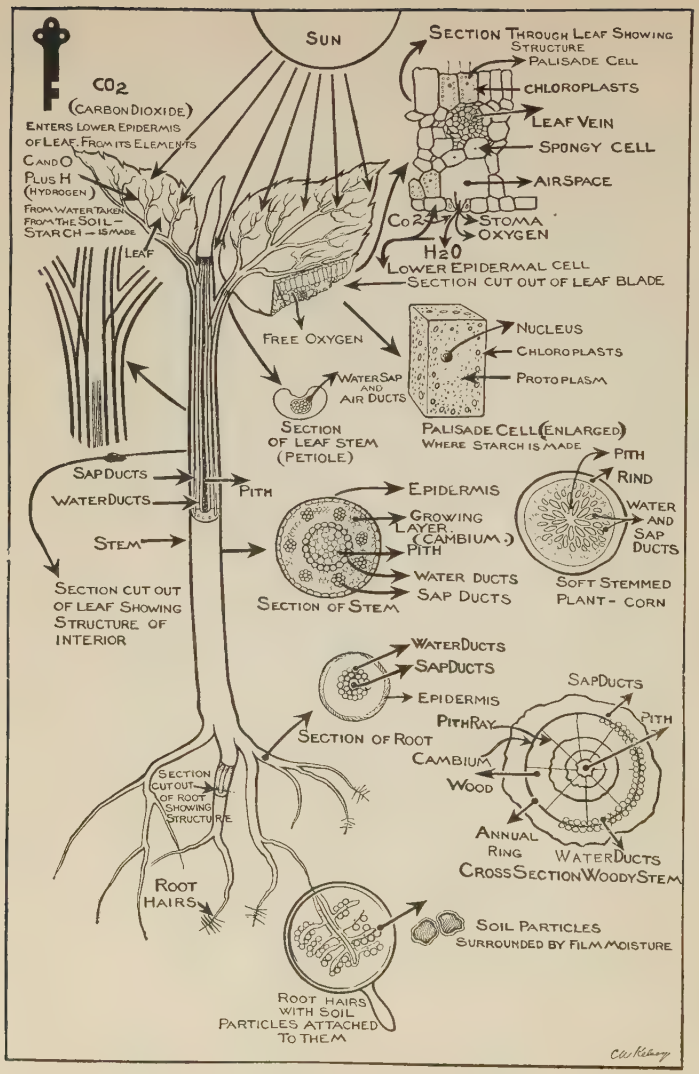
Science discovers law in Nature and makes it intelligible.
— Wood.

You know that a green plant will grow best in the sunlight. It turns its leaves toward and seems to reach out for the sun's rays. This means that a green plant requires the heat and light energy of the sun in order to grow. It has the remarkable power of absorbing the sun's energy and making it do a definite piece of work. Its green leaf can, with the help of the green coloring matter, put the heat and light of the sun to work combining air and water and from them make — food.

Animals cannot use water and air as food but they can eat the food which the plant makes out of the air and water. Animals cannot work without this food. Plants make possible the work of the world.

You already know that coal and oils are the remains of plants and animals living millions of years ago in the carboniferous age. These plants and animals were made by the sun at that time. It is now plain to see why coal and oils release heat and produce motion. Foods do the same thing in the bodies of animals. The manufacturing of shoes and the making of food both require the energy of the sun. The car shop and the human body both do work because fuels are used in them.

In the next two chapters are the details of the way a green plant makes food and fuel and why agriculture is the vast and fundamental industry that it is, making possible the work of the world.



KEY PICTURE 16. — THE GREEN PLANT AND ITS PARTS.

Study every detail of this picture until you understand the parts of the plant and their functions. How many functions of the plant are here shown? Explain. Continually turn back to this picture as you study this chapter.

CHAPTER XVI

THE WORK OF PLANTS IN THE PRODUCTION OF FOOD

See'st thou the fern and tree, the herb, the flower,
Have they not life as thine, and health and power?
Do they not breathe and eat and drink to be
Something they have in common, man, with thee?
— John P. Morris

Strip the world of its pellicle of soil — thinner relatively than the bloom on a peach — and you have destroyed all life. No wonder that we often call it the Divine Soil! — Wood.

What is dirt? What is soil? Can you tell? Did you ever think that water had anything to do with the soil? How do you think air, temperature, and dead leaves would affect the soil? Could plants grow in pebbles? in sand? What do you suppose makes soil good? Did you ever plant a garden? Did the seeds grow? How do seeds turn into plants? What color are most plants when they come above the ground? Does this mean anything to you? Did you ever hear that plants make food? No food in the world outside of salts can come from any source other than plants. Do you believe this statement? If foods are so important and plants make foods, how are we going to protect them from their natural enemies? That is a problem which is discussed in this chapter.

Some Practical Questions :

1. What kinds of soil in your community are thought to be the most valuable and why?

2. What kinds of soil are likely to stay wet and sticky a long time after a heavy rain? Do you find any gardens in your community hard to work because of this condition? Are these gardens productive?

3. Gardeners seldom cultivate the soil immediately after a rain. Why? Why do they often cultivate their gardens during a drouth?

4. Gardeners generally water their plants in early morning or late afternoon. Why?

5. Do we grow plants in the garden mostly for their flowers, their seeds, their roots, or their leaves?

Home Problem. — Plant one corn seed and one bean seed in separate pots of earth. Watch them develop day by day. Make a series of sketches of each every third day until each is six inches high. Label all parts as they develop. Note how each got out of the ground.

Field Problem. — Notice all the gardens on the way to and from school. Note the connection between the soil, lay of the land, and the plants in each. Note also the garden plans and determine which is the best all-round garden, with reasons.

1. Why Plants Are Important to Us

397. Environment and Green Plants. — Both climate and weather affect the small area of ground and the plants growing in it which you call your garden. Early or late frosts may ruin it. Heavy rainfalls may wash it out. Drouths may dry it up. These differences, you should remember, go back to our discussion of our solar system. They are all caused by the relation between our sun and our earth. Your garden, then, is closely related to the laws of our solar system. Our potatoes and our seasons are both controlled by the same laws. Explain.

398. The Importance of Green Plants. — During the years 1916, 1917, and 1918 we heard a good deal about war gardens. Millions of dollars' worth of food was produced in back yards so that more food might be sent to the Allied armies in Europe. As a matter of fact, green plants are the greatest factories in the world. Were it not for the home gardens and the farms we should soon starve. The raw mate-

rials out of which green plants manufacture our foods are mostly invisible and for this reason their work seems a mystery to us. A large proportion of our bodies was once air (gas). With this strange fact in mind you should be curious to study green plants, with special reference to their use of air and soil.

FIGURE 252. — A TYPICAL GARDEN.

What factors of the environment affect a garden? Why are the plants grown in rows?

2. SOIL AND PLANT LIFE

399. The Nature of Soil. — If you pick up a handful of soil from your yard, it appears to be simply a crumbling mass of dirt, but examined under a hand lens, it is found to be composed of small, individual particles of shiny, rough or irregularly edged quartz (kwôrts), mixed with other dark particles which do not glisten and are soft in texture. *Soil, then, as we find it, is pulverized rock plus dark particles formed*

of dead, decaying matter, — once a part of living things, both plants and animals, and for that reason called organic matter.

U. S. Dept. of Agriculture.

FIGURE 253. — PLANT ROOTS AND SOIL.

Note the roots going straight down for water and the granular nature of the soil.

This soil is made from hard rock by the process of *weathering*, which is brought about by the slow action of rain, running water, ice, frost, and wind. Much soil was once formed by the action of glaciers during the Glacial Period.

So the rock crust of the earth is covered with a very thin layer of life-giving soil. Yet it is a fact that some soils are better adapted to support life than others (Fig. 253).

400. How Soils Differ. — It is a common observation that garden soils differ greatly in color and texture in the same village or town.

Clay is composed of the finest kind of soil particles, which when moist cling together so that they cannot be separated or worked. On the other hand, *sand* is composed of such large particles that they will scarcely hold together even when wet and will pour from the hand like water. Such soil is easy to work, but has little plant food in it.

Subsoil, a common form found a few feet below the surface of the ground, is composed of finely pulverized rock, varied in color, finer than sand and coarser than clay. This soil has been largely produced by glaciers and has for this reason little plant food in it.

Sandy loam is a mixture of sand and subsoil with some organic matter added to it. *Clay loam* is a mixture of clay, subsoil, and organic matter, is hard to work except when slightly damp, is

fairly porous, and contains the elements needed by certain plants producing acid fruits or seeds.

Dark soils containing large quantities of organic matter are often called *humus* soils. Such soils are best for plants. Can you explain why? This organic matter always contains large numbers of angle worms. Can you see why? These worms do wonderful work in plowing up the soil and bringing into it much organic matter. Explain.

A very practical bit of work for you to do would be to discover what kind of soil makes plants grow best.

Suggested Experiment. — Take some sand, some clay, and some loam in equal amounts and plant in each kind of soil six pea or corn seeds. Give each soil equal amounts of water from time to time and set each in the same conditions of heat and light. Explain this. Watch for results, making records in your Science Discovery Book, and finally draw your own practical conclusions.

401. Soils Hold Water. — Liquids tend to rise up narrow tubes by what is called *capillary attraction.* A porous soil is full of *capillary spaces* which, if not broken up by cultivation, allow rapid evaporation of the soil water. Different kinds of soil have different water-holding capacities. The soil to be desired is one that will hold water long enough for plants to get what they need but not so long as to injure them. This means that something must be added to the sand to give it greater water-holding capacity and to the clay to make it more porous. What material would you suggest adding to the soil? Why?

402. Soil Cultivation. — The working of the soil in your garden does the following things for it. (1) It separates the soil into very small particles, and breaks up the capillary spaces. (2) It mixes the organic materials evenly through the soil. (3) It lets plenty of air into the soil to oxidize the organic materials and give life to the garden plants. (4) It prevents the excessive loss of water. Explain all these points.

3. The Seed and Plant Growth

403. Soils and Seeds. — Soils may be rich and possess plenty of water and air, but they are of no use to man until seeds are planted in them. What is a seed?

Laboratory Exercise. — After soaking some bean and corn seeds in water for from six to twelve hours remove the outside covering or *testa* of a bean seed and note the two halves or *cotyledons* (kŏt′-ĭ-lē′dŭnz) or seed leaves which are heavy and full of food. Can you see the advantage of this? What is their use to you? Carefully pry these cotyledons apart and observe the structure inside. Under a hand lens two tiny *leaves* should be visible with the veins clearly seen. How does the lens make them clearer? Note the

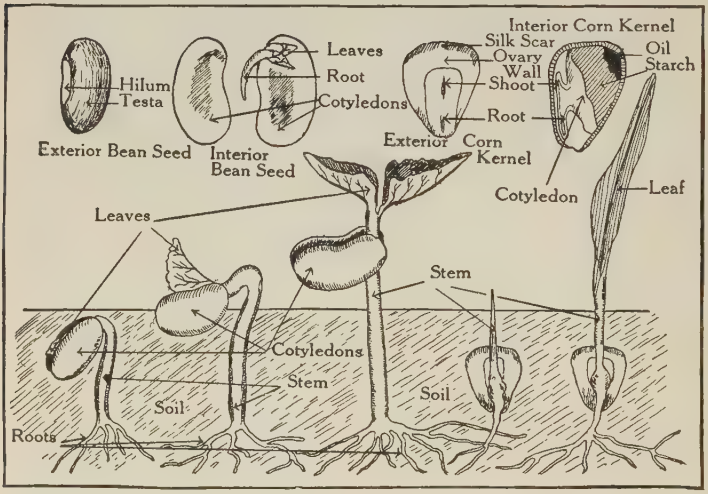


FIGURE 254. — SEEDS AND SEEDLINGS.

Carefully trace the changed position of the seed parts in each step of growth. Become familiar with the seed parts and their functions.

small pointed portion, the minature *root*, and the short *stem* where the little plant is fastened to the cotyledon. Here we have a tiny plant or *embryo* ready to grow and work when placed in the right environment. What is this environment? In what direction will the leaves grow? the stem? the root? Study the diagrams and be sure that you know thoroughly all the parts and their functions.

The corn kernel will show you similar structures, though shaped differently. If the kernel is split lengthwise, one cotyledon will be found instead of two. Its function is to absorb the food from the *endosperm* or stored food compartment found at one side full of starch and oil. The shoot or stem and the root are found where

you would naturally look for them. Compare the parts with those shown in the diagram and become thoroughly familiar with them.

What, then, is a *seed? It is a young plant (embryo) surrounded by a protective covering and containing stored food (either packed in it or in a separate compartment).* What is the *embryo? It is the young plant, alive, but inactive, in the seed.*

404. Plants Grow and Do Work. — In from four to fifteen days after the seeds are planted, the young plants begin to appear above ground. They have germinated. They are turning into *seedlings*. In growing they break their way through the earth. They do work. Explain. Plant some corn kernels and bean seeds and as they germinate compare them with the different stages shown in Figure 254.

405. Digestion and Growth. — Practically all seeds contain starch. This can be proved by putting a few drops of iodine solution [1] on the surface of any open seed. The seed will turn blue, showing the presence of starch. When heat and air come into contact with a seed, no growth occurs. But add water, which enters with the air into the seed through the *micropyle* (a tiny opening in the side of the seed) and a substance in the seed, called *diastase*, acts upon the starch and changes it to *grape sugar* so that it can be carried to all parts of the young plant in the seed. This changing of an insoluble substance (starch) to a soluble substance (sugar) is called *digestion*. This change can easily be demonstrated by boiling a few pieces of the stems of the seedlings in a test tube containing some Fehling's [2] solution. A change in color of the solution from blue to brick-red indicates the presence of sugar.

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[1] Iodine (ī'ō-dĭn) solution may easily be made by adding some crystals of iodine to enough 95% alcohol to dissolve them.

[2] Fehling's solution may be readily made in the following manner: To 500 cc. of distilled water add 35 grams of copper sulphate. This is called Solution 1.

To 500 cc. of distilled water add 160 grams of caustic soda (sodium hydroxide) and 173 grams of Rochelle salts. This is Solution 2. When needed, mix equal parts of solutions 1 and 2. Druggists will also furnish these two solutions in tablet form.

The oxygen in the presence of heat begins to slowly oxidize this sugar, starch, and oil in the seed, and more heat is released, which is the energy used by the young seedling in emerging from the ground. These young plants actually do work. Explain. What has now become of your seed? The food stored in it has now become part of *the roots, stem, and leaves* of the developed plant before you. What are the principal parts of any typical plant?

4. Plants and Soil Water

(Key) Demonstration 43 : *How does water get into a plant?*

Materials: A thistle tube; collodion (kŏ-lō′dĭ-ŭn) or a piece of animal membrane (sausage casing); a large-sized pill bottle with straight sides; two wide-mouthed bottles; a ring stand; ½ oz. of silver nitrate solution; and salt.

Note. — If collodion is not used set up the usual apparatus as shown in Figure 255. Firmly tie the animal membrane on the large end of the thistle tube.

Method: A. Pour a little collodion into the pill bottle and quickly revolve the bottle in a horizontal position to spread the collodion evenly on its sides. When the collodion stops running, lay the bottle aside until the collodion dries enough to come away from the sides of the bottle. Carefully remove the collodion in the form of a bag. This represents a plant cell and is made of practically the same material (*cellulose*) as a cell wall. Tie this bag over the small end of the thistle tube so that it is water tight. Make a concentrated salt solution and pour it slowly into the large end of the tube, filling the bag and one-half the tube. Mark position of liquid by a rubber band. Fasten tube in ring stand so that the bag is wholly immersed in a beaker full of fresh water. Set aside for a few moments and note what happens.

B. In a second bottle pour some water and a few drops of silver nitrate ($AgNO_3$) solution. Note what, if anything, happens. Next, after the collodion bag or animal membrane has been immersed some time in the bottle of water, place a few drops of the silver nitrate solution in the bottle. Note what happens.

Note. — It is known by chemists that silver nitrate always produces a white precipitate[1] in a salt solution.

[1] Precipitate: a substance, usually a solid, separated from solution by chemical or physical change.

Observations: What happens to the liquid in the tube? Is there more liquid in the tube now than before? Where could it have come from? Hold the apparatus between you and strong light and carefully observe the liquid in the bottle just below the bag. What do you see? Is there a flow of liquid out of the tube? Is there a flow of liquid into the tube? Give your proofs. What is the nature of the substance flowing into the bottle? Give your proof. In which direction is the flow the greater? How do you know? Lift the tube from the bottle of water. Wipe dry with cloth. Does it leak? Place back in bottle again. Does it leak? In how many directions? Does the flow become faster or slower as time passes?

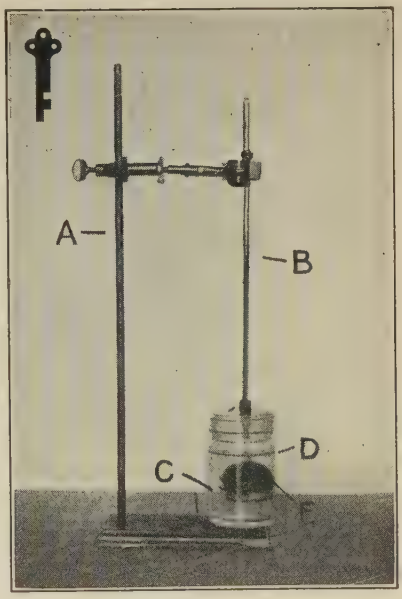

FIGURE 255. — (KEY) DEMONSTRATION 43.

A, ring stand; **B**, height of liquid in tube; **C**, fresh water; **D**, bottle; **E**, salt water in thistle tube (colored).

Be sure that you can see just what happens in this experiment and account for it. Know the use of each part and see how it compares with the parts of a plant.

NOTE. — This action of two liquids through a membrane which is ordinarily water tight is called *osmosis* (ŏs-mō'sĭs). But the two liquids acting through the membrane must be of different *densities*. Which liquid is the denser? In what direction is the greater flow? Suppose you exchange the places of the liquids, what would happen? Try it. Can you state a general law of osmosis?

While your osmosis experiment is going on examine some fine roots of radish or flax seedlings. Note the white, bushy fringe. Place one under a microscope. Note the long, hairlike projections growing out from the root surface. These are *root hairs*. Their function is to absorb the film moisture from the particles of soil. Note the cell wall, the transparent, granular protoplasm, and the attachment of this cell to the main root.

Compare the collodion bag or membrane with the root hair. What in the plant corresponds to the bag? to the salt-water? to the fresh water? to the small end of the thistle tube?

Conclusion: How does water get into a plant? Give proofs. Where does water get in? Do you suppose that any cell sap flows out? In which direction will be the greater flow? How do you know?

Practical Application: Table salt sprinkled on an asparagus bed kills the weeds. Why? Can you think of any reason why it will not kill the asparagus plants? This is a most important demonstration. Write it out in full in your Science Discovery Book.

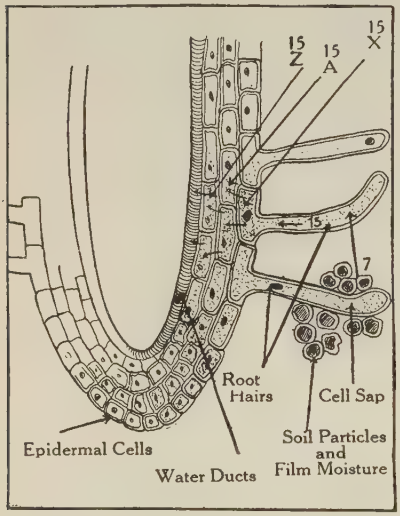

FIGURE 256. — ROOT HAIRS.

Very small, yet very important. Why? How do they accomplish their work? Why are their walls so thin? What do you think they really are?

406. Root Hairs and Soil Water. — A careful examination of a small root of a seedling under the microscope will show it to be made up of brick-like units which you now know are *cells*. But near the end of the root you will find growing out from the center of many of these cells a long, hairlike outgrowth. This is part of an *epidermis* cell of the root and is the *root hair, which is really a cell or at least a part of a cell* (Fig. 256). The cell wall can be plainly seen, as can the lining of protoplasm just inside, and the cell sap occupying the whole center of the cell. Somewhere in the cell a nucleus may be made out. Two things should be particularly remembered. (1) The cell wall is so very thin that soil water can soak through it, and (2) the root hairs are so numerous (480 of them have been counted on a root $\frac{1}{17}$ of an inch in

diameter in a space $\frac{1}{100}$ of an inch long) that they enormously increase the absorbing surface of the root (Key Picture 16).

407. How the Root Hairs Work. — As water moves over the particles of soil it dissolves from them all of the soluble soil materials. Just as soon as this soil water solution comes into contact with the root hairs, osmosis begins, because of the difference in density between the cell sap on one side of the cell wall and the soil water on the other side. Make up a definition of osmosis and see if it correctly applies to the process going on in the apparatus of Demonstration 43.

408. How the Whole Plant Gets Water. — With the absorption of water into the root hairs the problem of getting it to all parts of the plant is just begun. The whole root is a mass of tissues, each tissue having a special function. The *epidermal tissue* protects the root and absorbs water, the *cortex tissue* stores food and prevents evaporation of water, the *central cylinder* contains the *ducts* and stores food, while the ducts themselves carry air and water up and down the long axis of the root and connect with other ducts, in the stem, which extend up to the leaves. But all these tissues are composed of cells, with walls which have no openings. This means that liquids can pass from cell to cell only by osmosis and that the same laws that apply in the root hair must apply to every live cell in the root and in the whole plant. Study Figure 256. In this diagram, for the sake of illustration, the density of the soil water is marked 7 while that in cells A, Z, and X is marked 15.

409. How Does Water Get Out of a Plant? — Most of the water coming into a plant gets out again. It passes out through the small pores (*stomata*) on the under side of the leaf. The process is called *transpiration*. There must, therefore, be a continual stream of water passing out of the plant in order to leave a small amount of mineral in the plant.

There is but one part of mineral to each 400 parts of water. Minerals mean growth and thriftiness.

Demonstration 44: *Problem: Do plants give off excess water through their leaves?*

Materials: An earthen pot; a small thrifty potted plant; two bell jars; rubber tissue; and some cord.

Method: Tie the rubber tissue around the stem of the plant and over the top of the pot. Set the plant on a table in the sunlight and cover it with a bell jar. Observe after a half hour. Fill the empty pot with earth, cover it with the rubber tissue, and place it, like the other, under a bell jar. This second pot is the *control.*[1] Observe this jar after a half hour.

Observations: What has happened? Where did the moisture in the first instance come from? What was the importance of the rubber tissue? How does the control help you in drawing your conclusion?

Conclusion: Write out your conclusion in full.

Practical Application: Why do clouds form easily over forested regions? Why is it cooler along a street where trees abound? Why is the air in a greenhouse always moist? This is important to the well-being of the plant. Knowing what you do about soil water, why do you think transpiration must go on most of the time, if the plant is to grow? Why do plants grow little during a drought? Why do they grow rapidly just after a heavy rain? Write this demonstration in full in your Science Discovery Book.

410. The Importance of Plant Stems. — Study the Key Picture and try to tell what some of the uses of stems are, after answering the questions. Though the principal use or function of a stem is to hold the leaf up to the light, it must perform other functions in order to connect the leaves with the roots. One of these special functions can be determined by setting a branch of celandine (or even celery

[1] A control is a part of an experiment used as a basis for comparison, or a check on that part from which results are expected. In this experiment the pot containing earth is put in the same conditions as the potted plant. Only the plant is lacking. If something happens in the jar containing the potted plant and nothing occurs in the jar without the plant, you may conclude that the plant caused the difference in results. Can you see this?

will do) in some red ink over night. The ink will be found to have colored even the tips of the leaves red by morning. How did it get into the leaves? (Key Picture 16).

5. Leaves as Great Factories

411. The Great Work of Plant Leaves. — The most conspicuous part of your garden plants are their leaves. They have a most important work to do. You are looking upon a vast assemblage of factories, each going at full speed from sunrise to sunset. A simple demonstration will show that this is true.

Figure 257.—(Key) Demonstration 45.

Be sure you understand the use of every part of this apparatus, what the demonstration actually proves, and how and why it proves it.

(Key) Demonstration 45: ***Problem: When and where does a green plant make starch?***

Materials: A thrifty spotted geranium; a hydrangea; wood alcohol; a beaker; a Bunsen burner; an iron tripod; black felt cloth or black opaque paper; and iodine solution (Fig. 257).

Method: Cut several little squares of cloth and clip them to both sides of one or more of the hydrangea leaves and to the *green* parts of the spotted geranium. Place the plants with the cloth attached in direct sunlight from early morning until three or four P.M. Remove the cloth, cut off the leaves, and boil them in the alcohol over the burner until all the green color has been driven out. Carefully and thoroughly wash the leaves in warm water and place them between pieces of blotting paper until fairly dry. Put them in a strong solution of iodine for a few minutes (section 405). Remove them and place in blotting paper again or between two glass plates.

Observations: Do you find evidence of the presence of starch in any part of these leaves? Explain. In what part of the hydrangea leaves do you find no starch? in the spotted geranium? What prevented the making of starch in certain parts of the hydrangea leaves? What is necessary for starchmaking? Did the cutting off of the light interfere with the starchmaking in the covered parts of the spotted geranium leaves? Can you see why no starch was made in the uncovered white parts of these leaves? What other condition is necessary in order that plants may make starch?

Conclusion: When and where does a green plant make starch? Why were the plants placed in the sunlight in the early morning and brought in late in the afternoon? Write a complete account of this demonstration in your Science Discovery Book.

412. The Green Leaf, a Great Factory. — The substance which has much to do with starchmaking in the leaf can be dissolved out of the leaf by alcohol. It is called *chlorophyl* (klō′rō-fĭl) or *leaf green.* It is located in small bodies of protoplasm called *chloroplasts,* which move about in the cells of the leaf. These bodies, with the help of the sun's energy, are able to combine water and carbon dioxide in such a way as to form new compounds which we know as starch and sugar (Fig. 258).

This process may be indicated by a formula as follows: Six molecules of carbon dioxide 6 (CO_2) plus five molecules of water 5 (H_2O) equal one molecule of starch ($C_6H_{10}O_5$) plus six molecules of oxygen 6 (O_2). You see that six molecules of oxygen are produced in the process. This is a by-product of the leaf factory. We breathe this pure oxygen.

Think of it! The green leaves of the garden may absorb dirty water from the home and gases from smoking chimneys, giving you in return pure oxygen and delicious vegetables full of sugar and starch. The green leaf is a miracle factory. Our lives depend upon green plants. Try to give a definition of your own of starchmaking. Scientists call the process *photosynthesis* (fō′tŏ-sĭn′thĕ-sĭs).

413. How the Green Plant Affects the Atmosphere. — It is easy to show that green plants take in CO_2 and give off O.

Suggested Experiment. — Secure a small, thrifty potted hydrangea or geranium plant; a bell jar; a smooth piece of heavy tin,[1] or better, the plate of an exhaust pump with electric connection terminals; vaseline; a candle; insulated copper wire; a shallow dish

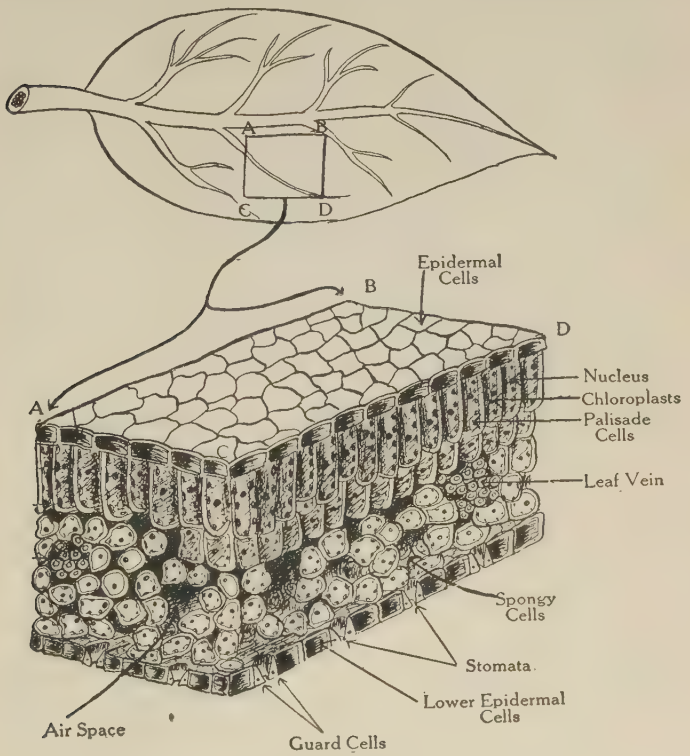

FIGURE 258. — A LEAF SECTION.

Here are the real manufacturing rooms of the green plant. What is made here? By what is it made? from what? Show how the leaf is adapted for its work.

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[1] If the tin plate is used instead of the exhaust pump table, two very small holes should be drilled through the tin near one edge just large enough to allow the insulated wires to pass through. The wires should then be sealed in these holes by the use of melted paraffin.

(Syracuse watch glass); limewater; a battery of dry cells; one 2-inch length of fine chromium wire; and an electric button (Fig. 259).

A. At the beginning of school on a sunny day, place the plant on the exhaust pump table. Attach two 6-inch lengths of the insulated wire to the upper terminals and connect them at their ends, by the use of about one inch of the fine chromium wire (see diagram). Place the candle under this connection so that its wick touches it. Place some limewater in the shallow dish, light the

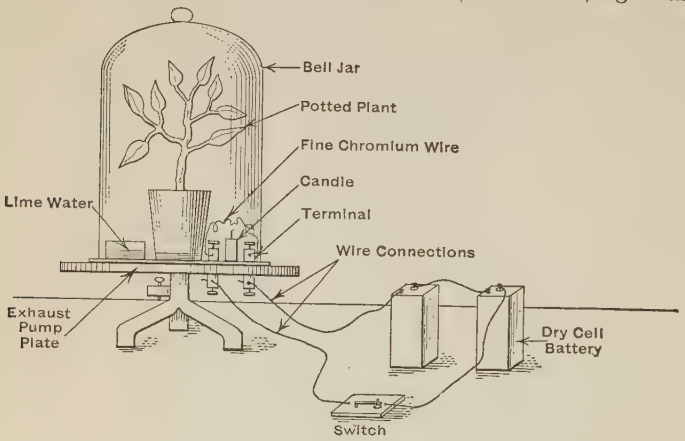


FIGURE 259. — HOW PLANTS HELP PURIFY THE ATMOSPHERE.

Study this apparatus and see how it is used before attempting to use it. Then set it up as shown above and produce the results. What have you proved? Explain.

candle, and place the bell jar over the whole apparatus (plant, limewater, candle, connections). Seal the jar to the table with vaseline so that it is air tight. This can be done by smearing the bottom edge of the jar with the vaseline before putting it in place and by covering the plate also with a thin film of vaseline. Be sure to note the time when the jar is put in place. Watch carefully and note what happens to the candle and the limewater. Note how long the candle burns.

B. Now connect the battery of dry cells with the lower terminals and with a switch. Leave the whole apparatus, with the switch open, until the close of school. At this time, noting the hour, close the circuit of your electrical apparatus. This will cause the fine wire to become red hot, and it will light the candle again. Note how long the candle burns.

What made the candle burn at first? How long did the candle burn? What made it go out? What happened to the limewater? Account for it. What gas now filled the jar? Was there any other substance there? What took the place of the oxygen? How long did the candle burn the second time? What allowed it to burn? What had happened to the carbon dioxide (CO_2)? Where did the oxygen come from? Why did the candle burn longer the second time?

How do green plants affect the air about them? Give your proofs.

Are green plants a health asset in a living room? Why are public parks valuable? Why are the mountains good for people who need fresh air or a change? Explain fully your answers. What is the importance of CO_2 to green leaves?

414. The Green Leaf Compared to a Saw Mill. — The leaf is a factory and the chloroplasts are the machinery. If you compare the leaf to a saw mill it will help you to remember the essentials of the starchmaking process.

1. Manufacturing plant.	Leaf.	Saw mill.
2. Machinery.	Chloroplasts.	Saw.
3. Power.	Sunlight.	Steam or water power.
4. Raw materials.	CO_2 and H_2O.	Logs.
5. Finished product.	Sugar and starch.	Lumber.
6. By-product.	Oxygen.	Sawdust and slabs.

Now look at any garden and try to realize the enormous amount of work done each day by each of these factories. Then think of the amount of work done each day in your state, in the United States, or in the world from sunrise to sunset, work that goes on regardless of the whistle or the clock.

Why is the corn crop always good during a hot summer? Why does California produce such an abundance of large fruits?

415. Plants Make Other Foods. — Certain plants, such as the castor oil plant, make large amounts of *oil*. Since the same elements (carbon, oxygen, and hydrogen) are found in *fats* as in starch and sugar, it is believed that the protoplasm of the plant can turn sugars to fats.

These fats are used to protect the seeds from decay and also to release heat in oxidation. *Proteins* are made in the cells through the combining by the protoplasm of the elements in fats and sugar with the dissolved minerals (phosphorus, sulphur, nitrogen, and several others). These minerals are brought into the plant by the root hairs. Plants also make other substances (fruit acids, vitamins, etc.), valuable as foods.

416. Green Plants "Breathe." — Many people think that green plants "breathe" in carbon dioxide and give off oxygen in a manner just opposite to that in the breathing of animals. This is entirely wrong. Plants do take in carbon dioxide and give off oxygen, but not in respiration. This is done in photosynthesis.

Suggested Experiment. — Place a few pea seedlings in a large-mouthed bottle, cork tightly, and set aside for some time. Now draw off some of the air in the bottle with a pipette and run this air through limewater. Note result. What are your conclusions? Explain fully.

Why, then, does a plant need oxygen? For the same reason that you do, — to oxidize its tissues or food and release energy to carry on its life activities. The wastes of this process are carbon dioxide, water, and nitrogen wastes. Now note this remarkable fact. In starchmaking, the sun's energy is preserved in the starch, sugar, and fats, in the form of stored energy. In "breathing" (respiration), oxygen causes these foods to burn and the stored energy becomes kinetic and work is done in growing or moving. With these facts in mind try to answer these questions:

1. When are starchmaking and respiration carried on?
2. Where can each process be carried on?
3. What are the raw materials used in each process?
4. Why is breathing so closely connected with oxidation?
5. What is the useful product in starchmaking and oxidation?
6. Which process in question 5 builds up tissue and which tears down tissue?

Write this out in full in your Science Discovery Book.

417. The Green Plant a Wonderful Engine. — Every cell in a green plant, then, may be called a miniature engine. It is a live engine which absorbs certain raw materials, makes fuels from them, and then burns these fuels in the body of the plant. You cannot go into your back yard or garden and eat a part of your ash heap and live, but the plant can do it and from these ashes produce your daily oxygen, bread, meat, and potatoes. The green plant stands between you and death. Try to name one food which you eat which does not come either directly or indirectly from the plant. You can probably name none, with the possible exception of salt.

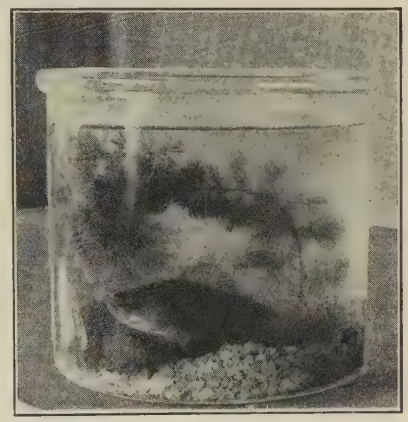


FIGURE 260. — THE BALANCED AQUARIUM.

What three factors make up this aquarium? Make a copy of this picture in your Science Discovery Book and indicate by arrows what substances pass between the living things here shown.

418. The Balanced Aquarium. — A beautiful example of the way the green plant is useful in keeping animals alive may be seen in the balanced aquarium. Such aquariums are found in many homes and probably form a part of the equipment of your science room. Here the green plants give food to the fish and supply them with oxygen necessary to their life (Fig. 260). Explain.

On the other hand, the animals contribute very materially to the life of the plants. The fish in "breathing" uses oxygen and gives off CO_2 just as the plant does, but in much larger quantities because it is active. This the plant needs. Why? The fish also gives off liquid wastes which contain nitrogen compounds also needed by the plant. Explain this statement. Both plants and animals live together very happily.

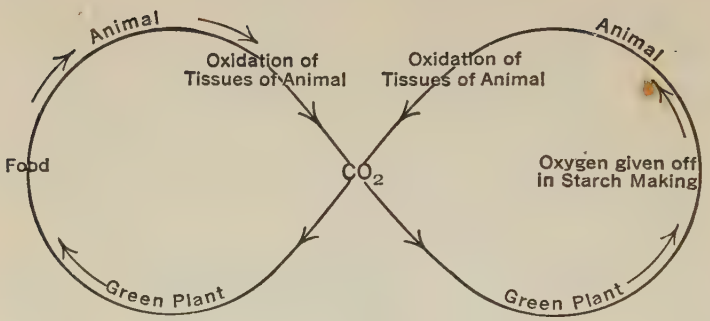


FIGURE 261. — THE CARBON-OXYGEN CYCLE.

Compare this diagram with what goes on in the balanced aquarium. Start at any point and follow round the circles, telling what each step means as you proceed.

The water never needs to be changed. Why? More water must be added now and then. Why? Neither plants nor fish need to be fed. Why? This aquarium may be sealed and the fish still live. Explain.

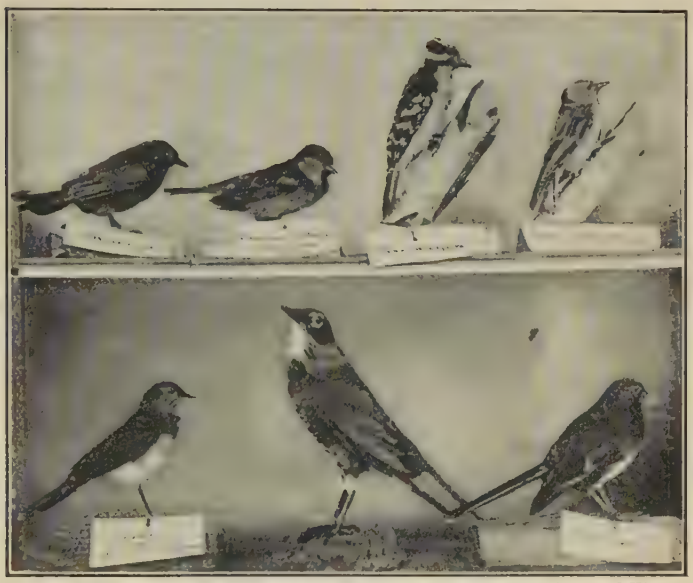
FIGURE 262. — THE POTATO BEETLE.

One of many insect pests in the garden. How can this insect best be controlled?

It may be added that what goes on in the small aquarium also occurs in a larger way in the world about us. We depend upon the plants. They depend upon animal products. A farmer once said that if he were dependent for his living upon a few hives of bees, a good orchard of apple trees, a few cows, and a good garden, he could live. Explain fully his statement and prove or disprove its truth (Fig. 261).

419. Green Plants and the Work of the World. — No human

work can be done without plants. Our great manufacturing centers, such as New York and Pittsburgh, are possible only because of the green vegetables, fruits, and cereals produced by green leaves in the truck gardens, orchards, and



American Museum of Natural History.

FIGURE 263. — SOME COMMON BIRDS.

Try to learn the name of each. By reading the bird diet chart find out the food of some of these birds. Which do you think the most valuable to man? Why? Which one is not protected by law? Why?

farms of the country. Men eat these foods, release energy from them, and with this energy do work in our great factories. It is now believed that the home garden was one of the important factors in the winning of the World War. Can you explain this?

6. THE PROTECTION OF GREEN PLANTS

420. Man's Allies. — Probably the most valuable helpers of man in the garden are the birds. The robins, bluebirds,

kingbirds, martins, wrens, cuckoos, woodpeckers, and many others are all to be desired about the home because of their diet of insects (Fig. 263). Study the bird food chart and determine what birds are useful to us (Fig. 264a). Placing the right kind of bird houses at the proper places in

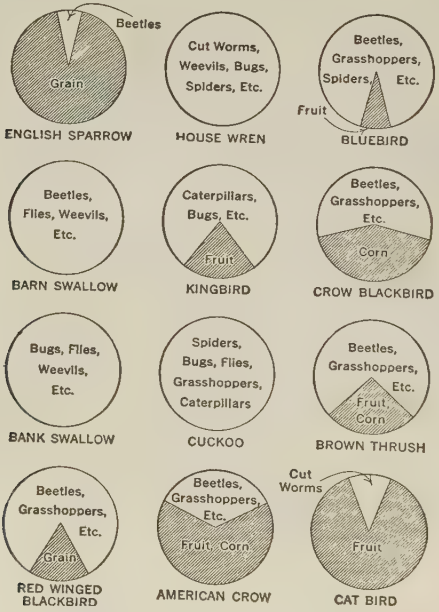


FIGURE 264A. — BIRD DIETS.

Which are our best friends among the birds here listed? Why are most of these birds protected by law? Which are not protected? Why?

your garden will always attract the wrens, martins, swallows, woodpeckers, and native sparrows (Fig. 264b). We should at all times protect our native birds by seeing to it that the laws prohibiting their destruction are obeyed. Recent state and federal laws (notably the Underwood Tariff Law of 1919 which includes a paragraph protecting all migrating birds within the territory of the United States) have already increased greatly the numbers of

robins in the country. Some state laws (notably the Lacey Bird Law in New York State) and government and private reservations have helped considerably in increasing the number of useful birds. Explain.

FIGURE 264B. — BIRD HOMES.

Here are some artificial houses for birds that any boy or girl can make. They attract the birds about the home. They should always be so placed, however, that cats cannot reach them. How may this be done?

421. Interdependence of Plants and Animals. — The owner of any garden depends upon the garden for his food. So do the insects and plant disease germs which make the garden their home. Still, the birds and friendly insects depend upon the destructive insects for their food. Thus every living thing related in any way to your garden is working at its best to obtain nourishment for the protoplasm of its body cells. From this standpoint one living thing has just as much right to live as another.

It is man's problem so to adjust and control the balance

of nature, that he may spare and protect the organisms which help him in growing and preserving his foods, by destroying or keeping in check other organisms which destroy those foods. In some cases this balance has been kept in a perfect condition; in others it has been lost with disaster to man.

In the years to come the feeding of the multitudes in our great manufacturing centers will be possible only by a most careful study of the intimate relations between green plants and the soil, air, and water; by the proper use of organic soil ingredients; and by the control of plant enemies through a more effective use of man's natural allies.

SUMMARY

Green plants manufacture *food* for man from *soil water* and *air*. Soil is largely composed of pulverized rock and organic matter, brought to this condition by the process of *weathering*.

When properly cultivated, soils allow the entrance of water and air and hold them for a long time. *Seeds* placed in such soils begin to grow or *germinate*. The young plant or *embryo* in the seed breaks ground and the sleeping plant develops *roots*, *stems*, and *leaves*. It grows and does work.

To grow, the young plant must have *soil minerals*. To get these into the plant tiny *root hairs* absorb dissolved minerals by the process of *osmosis*. The *stem* carries these dissolved minerals up to the leaves where they are used in making foods.

The green leaves manufacture *starch* from *carbon dioxide* and *water* and give off the excess *oxygen* so necessary to animals. They also give off water in the process of *transpiration*. Plants need oxygen just as animals do and they make *fats* and *proteins* from sugars and soil minerals.

Insect pests, *disease*, and *weeds* continually fight plants useful to man. All these should be killed. On the other hand, there are *insects* and *birds* which are of great value to man. We should protect these latter animals and encourage them to visit us by offering them food, building bird houses, and passing laws to protect them from destruction by the cruel and thoughtless.

The whole world is *interdependent* and nature strikes a *balance* between living things. Man has disturbed some of these balances. He should restore those which help provide his food supply.

Remember that :

1. Green plants can be grown because there is a layer of soil over the surface of the earth.
2. Soil cultivation is absolutely necessary for proper plant growth.
3. Green plants are the greatest factories in the world.
4. Plant growth is sometimes greatly aided and sometimes retarded by weather conditions and by plant friends and enemies in the shape of animals and other plants.
5. Green plants make animal life possible — they make the mineral kingdom into food for the animal kingdom — they stand between the animals and starvation.

THOUGHT QUESTIONS

1. Why does a tree have a trunk and branches? Do these parts do work?
2. Name ten very important food plants. Which of these are used mostly to keep animals alive? Which are used mostly by man? Are there any plants used as food by both man and lower animals? Are such plants used in the same way by both man and animals?
3. Show how you lift a book by the energy of the sun.
4. A cat likes meat. If it ate meat alone, would it be in any way dependent upon plants? Explain.
5. Plants are said to be good for living rooms, but bad for sleeping rooms. Explain.
6. Some plants will badly wilt by noon on a hot day in summer, but the next morning will be standing straight up in a fresh condition. Explain.
7. Why can weeds be killed by sprinkling the ground about them with salt?
8. Why are city parks often called " breathing places "? Why are they healthful?
9. How do plants directly affect the farmer, the carpenter, the tailor, the shoemaker, the physician, the druggist, yourself?
10. Prunes and raisins swell up when placed in water. Why?
11. If soaked prunes are placed in salt water, they shrink. Why?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Bailey. Manual of Gardening. The Macmillan Co.
Barnes. House Plants. Doubleday, Page and Co.
Bennet. The Vegetable Garden. Doubleday, Page and Co.

Cole. Rocks and Their Origin. The Macmillan Co.
Craigin. Our Insect Friends and Foes. G. P. Putnam's Sons.
Dugmore. Bird Houses. Doubleday, Page and Co.
Dixon. The Human Side of Plants. F. A. Stokes Co.
Duncan. Home Vegetables and Home Fruits. Charles Scribner's Sons.
Elliott. Romance of Plant Life. J. B. Lippincott Co.
Hawkesworth. The Adventures of a Grain of Dust. Charles Scribner's Sons.
Herrick. Insects of Economic Importance. The Macmillan Co.
Kellogg. Insect Stories. D. Appleton and Co.
King. The Soil. The Macmillan Co.
Moore and Halligan. Plant Production. American Book Co.
Rockwell. Around the Year in the Garden. The Macmillan Co.

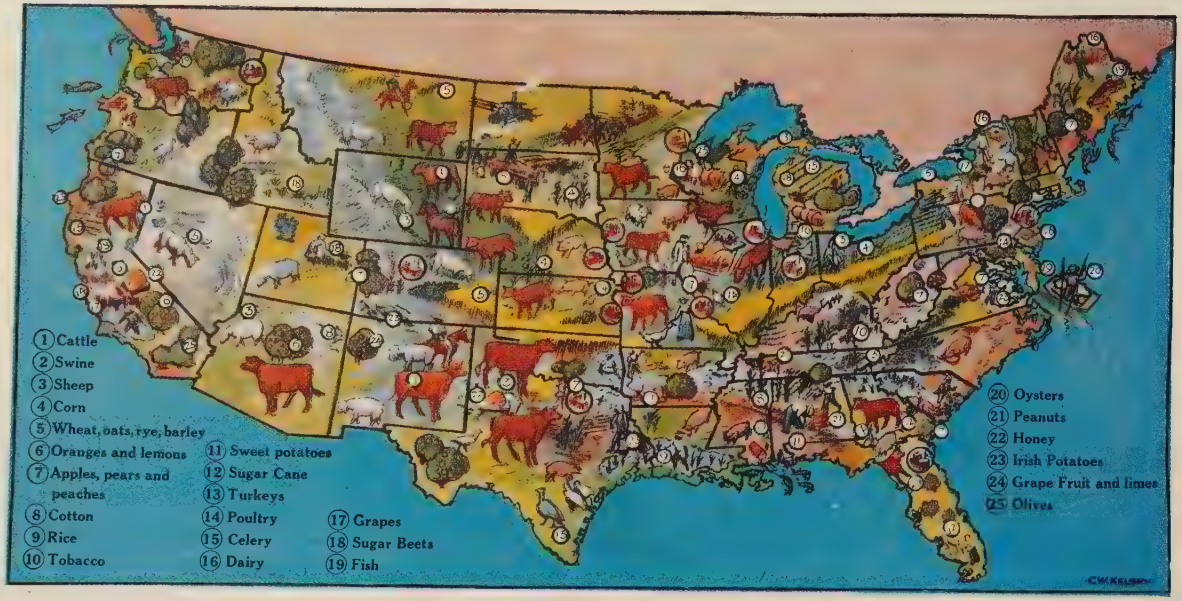


PLATE IV (KEY PICTURE 17).—WHAT OUR COUNTRY PRODUCES.

Study this picture carefully until you know at least 20 of the 25 important products listed here. In what products do certain States seem to specialize? Explain. What products seem to be common to a large number of States? Explain. Why are these products so abundant where indicated?

CHAPTER XVII

THE WORK OF SOLAR ENERGY AND ENVIRONMENTAL FACTORS IN AGRICULTURE

Heroes who conquered many a field
Of hard and sterile soil—
Who made the sturdy forest yield
To unremitting toil;
Heroes who did not idly stand,
But dealt such fearful blows
That acres, broad, of worthless land
Now blossom like the rose.
—Heroes of Industry: G.P.R.

Had there been no soil, had the rocks not decayed, there had been no you and me.—John Burroughs.

Why is farming so important to you? Suppose that all farmers went on strike; what would happen? What do you know about farming? Farming was no easy task in the pioneer days in this country. Why? It is not very easy now. Why? Do you know of any important problem which the present-day farmer has to solve? Why do many farmers put fertilizers in the soil? How do farmers increase their crops? How do they farm in the dry areas of the West? In the swamp lands of the South? What are some enemies of the farmer? What are some friends? Why is agriculture the most important industry?

Some Practical Questions:

1. What farms in your neighborhood are the most valuable? Why?

2. Why is the farmer the most independent man in a community?

3. Tell what would happen in this country if all farmers went on strike.

4. Make a list of all the industries of which you can think which depend in any way upon the farm.

5. Why is farm work considered hard? What is being done now to make it less difficult?

Home Problem. — If you live on or near a farm, find out from some one who has had the experience, or write out from your own experience, the complete history of any one crop grown on it.

Field Problem. — While on a trip or a walk through the country compare farms, determine the best, and give your explanations of the cause of the differences between the farms observed.

FIGURE 265. — NATIVE PLOWING IN EGYPT.

Note the crudeness of this plow, — two sticks fastened together. Yet it breaks up the soil, — a necessary process in growing crops. Explain.

1. How Primitive Men Secured Food

422. Soil and Life. — The whole surface of the earth is a solid mass or crust of rock; more than half of it is oxygen and the rest silicon and other elements. The soil as we know it is the merest film of pulverized rock spread very unevenly over the surface of this solid rock. But in this soil film is life. Explain.

423. Man and the Soil. — The greatest need of both savage and civilized man is that of food, for both are machines and need fuel to release energy in order to do work. Explain. Consequently there was a terrific

FIGURE 266. — THE MODERN PLOW ON THE BIG FARM.
Explain its great advantages. What is the source of energy here?

struggle for existence among early men and the result was the change from savagery through barbarism into civilization.

424. Tilling of the Soil by Early Man. — There is very good evidence that primitive man used the crudest kind of tools, few in number and variety. By means of them the soil was turned, cultivated, and harrowed. Crude rakes, shovels, axes, knives, hoes, and sickles were all very gradually developed as modifications of the inclined plane. Land was cleared by fire and the lever removed stones, stumps, and roots. Now the modern farmer uses the power tractor to do much of his work (Fig. 266). Yet there are more than 20,000,000 horses still working for man on the more than

6,000,000 farms of this country in the production of food for the nation (Fig. 267).

425. Early Methods of Producing Foods. — During all the centuries of early human history, plowing was done with oxen by the use of a wooden plow with an iron shoe. Sowing of seed was done by hand.

The harvesting of the crops was still more laborious. It was done with a small sickle, a crescent-shaped implement

FIGURE 267. — THE COMMON PLOW.

Much small farm plowing is done this way to-day. How is this plow an improvement over that shown in Figure 265? What is the source of energy here?

with a sharp edge. The invention of the scythe gave man a tool which could do 20 times the work of the sickle. Next came the cradle, a scythe with two or three wooden prongs set parallel to it and above it (Fig. 268). From the field the grain was carried in wagons to the threshing floor, where the grain kernels were beaten out by the flail.[1] This grain was then placed in bags and carted to the nearest mill to be ground into flour or meal.

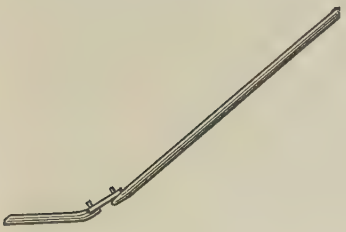
[1] Flail: an instrument made of two sticks of unequal length loosely fastened together at their ends with leather. This was used to pound out the grain on the barn floor (Fig. 268).

2. Present-Day Agriculture

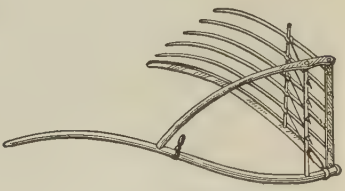
426. Agriculture in the United States. — Up to the year 1850 the great migrations of land seekers ended at the western

A Sickle

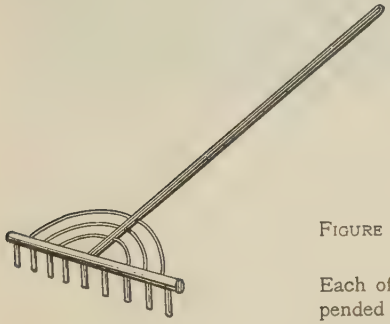
A Scythe



A Flail



A Cradle



A Hay Rake

Figure 268. — Some Early Harvesting Tools.

Each of the above harvesting tools depended upon the muscles in the arms of men for its proper use.

borders of the extremely fertile Mississippi River basin. Covered with alluvial deposits, this basin produced all the common food crops in enormous quantities. Here is the

region of greatest productiveness. Here is the most complex network of railroads. Here is a very thrifty and prosperous agricultural population, sound, wholesome, and fully American. [Study Plate IV (Key Picture 17).]

427. Two New Agriculture Problems. — The increased population of the country made agriculture on a large scale

Ewing Galloway

FIGURE 269. — A COMBINED REAPER, THRESHER, AND BAGGER.

Some improvement over cradle and flail! Horse-drawn harvesters are superior to tractors in the hilly country of the Far West.

necessary. Thus, the nineteenth century was marked by great improvements of agricultural machinery.

A second factor of importance was the gradual wearing out of the soil in the east through continuous cultivation. This produced the abandoned farm, and was a factor in causing the westward migrations. To-day the agriculturist must have considerable knowledge of soils, fertilizers, drainage,

aëration, and the like, to which the early farmer never gave a thought.

428. Harvesting the Crops. — It is a big jump from the cradle to the reaper, binder, and thresher in less than one hundred years. In 1834 Cyrus McCormick patented the mowing machine. In 1873 the self-binder appeared. This did the work of binding the grain into bundles as well as

FIGURE 270. — EROSION.

How farmers lose their land. How does erosion affect crops? How may it be stopped?

cutting the grain and then dropped these bundles at regular intervals so as to be easily loaded into wagons. A few years later the combined harvester and thresher appeared. This machine was drawn in the field by many horses. It cut the wheat, bound it into bundles, threshed the grain, put it in sacks, and tied them up ready for the mill or elevator.

429. Loss of Soil Fertility. — Experiments and observations have shown that the principal causes of the loss of soil

fertility are: (1) The soil may cease to hold water properly; (2) it may cease to grow bacteria properly; (3) it may lose its organic matter, largely by erosion (Fig. 270); (4) the nitrogen may be leached or washed out by rain; (5) the plant food may be used up by growing too much of one kind of crop.

3. Methods of Increasing Crops

430. Methods of Renewing Soil Fertility. — Soils may be renewed in several ways as follows: (1) Mixing prepared

Figure 271. — The Mohawk Valley in New York.
One of the most fertile river bottoms in the world. Explain.

fertilizers and manures with the soil; (2) planting to clover or alfalfa; (3) allowing the land to lay fallow or idle for a few seasons; (4) inoculation of the soil with bacteria; and (5) the rotation of crops.

Fertilizers contain nearly all the essentials for plant growth, but the rich soil in some of our agricultural regions makes their use unnecessary (Fig. 271). However, in 1919

more than $100,000,000 was spent on fertilizers. In all fertilizers there are varying amounts of nitrogen (N), phosphorus (P), potassium (pō-tăs′ĭ-ŭm) (K), calcium (kăl′sĭ-ŭm) (Ca), sodium (sō′dĭ-ŭm) (Na), and sulphur (S). Every one of these elements is needed by plants to build tissue and carry on their life functions.

431. Effects of Fertilizers upon Plant Growth. — In general, nitrogen produces much foliage in plants, while

FIGURE 272. — EFFECT OF FERTILIZER ON CORN.

Do you see a difference in plant growth here? Commercial fertilizer made the difference. Explain.

potash produces many seeds. Phosphorus seems to be necessary to the proper growth of corn. Wheat will not thrive unless calcium is in the soil and all plants must have some calcium in order to absorb other minerals from the soil. Thus, of all the fertilizers, calcium can least be spared. Sulphur goes to the making of new tissues. For the best all-round results barnyard manure is good. Its value in the United States in one year is estimated at $2,353,000,000. It increases the average yield an acre in the country by more than $3 each year. How much would this be for the whole country? (Fig. 272.)

432. Rotation of Crops. — A famous German chemist, von Liebig, proved that plants differ in the kinds of soil elements which they require for their growth. It is plain, then, that too many crops of one kind on a given field may use up the soil elements which the crop needs for its growth. To avoid this, the wise farmer rotates his crops. *Crop rotation is the changing for a given time of the kind of crop grown on a given field.* Rotations vary in duration (usually from one to five years) according to the crops planted. Such rotations (1) give an added return, (2) prevent the total loss of any of the important soil ingredients, (3) help to control the weeds, fungi, and insects, (4) keep up the humus supply, (5) save labor, (6) systematize farming, and (7) finally remove poisonous ingredients from the soil. Explain each of the above good points of crop rotation.

An experiment in England showed that when wheat was sowed continuously upon the same plot of ground for twelve years the average yield was 12.2 bushels an acre. But when a four-year crop rotation was followed on the same piece of ground, the average yield an acre was 28.6 bushels. In barley, twelve years without rotation produced 17.35 bushels an acre. Rotation of crops covering twelve years yielded 29.60 bushels an acre. Five-year rotations are approved by the best agriculturists. For example, a good rotation is the planting of corn, oats, wheat, grass, alfalfa and then corn again. If one-third of a farm is under rotation, say to corn, oats, wheat, clover, and timothy, this one-third will produce a greater crop than the other two-thirds without rotation. The increased value of farms under rotation, to say nothing of the increased returns from the crops on such farms, can hardly be estimated.

4. Putting New Lands to Work

433. New Land Problems. — The farmers of the West have long tried to push on into the dry lands of western Nebraska, Kansas, and Iowa, hoping to escape competition with their fellows, but they have faced a great obstacle in the lack of water. Can you explain this? To get a living

out of the soil was a hard task. Some have been successful, however, by the use of a special and interesting process.

434. Dry Farming. — It often happens that no rain falls in the western Nebraska region during the summer, for two successive years. Plants must have water. During the winter, deep snow covers to great depths this section of the country. In the spring it sinks into the soils. At once the farmer puts in his crops and begins to cultivate the soil to

U. S. Dept. of Agriculture.

FIGURE 273A. — ORCHARD IRRIGATION.

Why are the ditches far apart here? Why are they dug for a considerable distance on each side of the trees?

form a mulch on its surface. He continually breaks up the capillary spaces through the soil and so prevents the evaporation of water. Thus otherwise waste acres are brought under cultivation, principally in growing alfalfa, by the process of *dry farming*. Why is it given this name?

435. Reclamation Projects. — (1) *Irrigation.* One excellent example of irrigation dams is the Roosevelt Dam on the Salt River, a tributary of the Gila (hē'lȧ) River,

which flows in turn into the Colorado River. All this region is a desert. A few stunted mesquite and cactus plants, with now and then a jack rabbit or a rattlesnake, are the only signs of life in these vast areas. But this desert soil is extremely rich in the minerals necessary for good plant growth. Why could not plants grow there? Explain. By damming small streams far back from the area to be watered, enough water could be stored to be distributed in ditches for hundreds of square miles. This would give life to plants (Figs. 273a and 273b).

FIGURE 273B. — IRRIGATION OF CROP LANDS.

Why are ditches dug between the rows? Where does this water come from? Where and why is this method used?

The Roosevelt Dam was built and the city of Phœnix (fē'nĭks), Arizona, nearly 100 miles away, has become a great fruit center because of this work. The desert here blossoms like a rose. Egyptian cotton, tropical fruits, potatoes, apples, peaches, olives, and garden vegetables grow with great luxuriance with the thermometer 110 or more in the shade. Other great irrigation projects are on the way in other parts of the Great American Desert (Fig. 273c).

The practical value of this work is seen in the article which follows.

NEW HOMES FOR 3,000,000 IN BIGGEST IRRIGATION PROJECT HARNESSING THE COLORADO RIVER

Will Open Vast Waste for Farming and New Industries

Annual Floods to End

Three sites for big dams are already selected. These will develop 1,700,000 horse power. Their waters will tap 69,000 square miles and will irrigate 1,000,000 acres of land.

— *New York Times*, Jan. 21, 1923.

(2) *Swamp Reclamation.* In Florida, Louisiana, and other southern states, the land is extremely rich, but it is largely under water or water soaked. Here we have the other extreme. Absence of water will prevent plant growth. Too

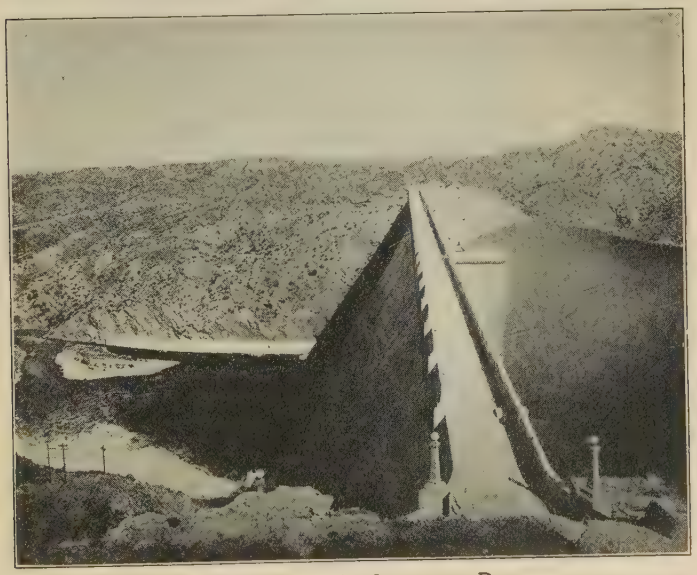


FIGURE 273c. — AN IRRIGATION DAM.

The Elephant Butte Dam, — the largest of its kind in the world. This dam makes millions of desert acres fertile. Explain.

FIGURE 274. — DRAINING SWAMPS IN FLORIDA.
Name several advantages gained by this method.

much water will do the same thing. Why? Instead of irrigation ditches, drainage ditches are dug. These drain off the excess water and allow the air to enter the soil. Warm air dries the soil, changing the soil's sour nature and thus permitting plant life to thrive (Fig. 274).

U. S. Dept. of Agriculture.
FIGURE 275. — WHEAT IN BUNDLES READY TO BE THRESHED.
How will this work be done?

5. How the World Is Fed

436. Some Important Crops. — The most valuable single plant in the world is wheat. Explain. The second is the potato and the third is corn. In amount, the corn crop exceeds all others.

If the corn crop of a recent year were placed in wagons, 50 bushels to a load, and each team (horses and wagons) were 20 feet long, this train of wagons would reach nine times around the world at the equator. (For amounts and values of our annual crops study any recent annual report of the U. S. Department of Agriculture.)

437. Some Uses of Corn. — This grain is mostly used as fodder for animals. Much corn is also used as human food

U. S. Dept. of Agriculture.

FIGURE 276. — CORN IN THE SHOCK.

What conditions of environment will make such corn possible ?

in the form of corn meal, corn flakes, corn bread, etc. Corn syrup is used in candy manufacture. Corn oil is used in cooking. Alcohol is made from corn. The corn stalks are made into paper and wall board. The pith is used in high explosives and in the water-tight compartments in the hulls of ships.

438. Other Crops. — Oats, food for man and beast; hay, a fodder for all animals; cotton, the most important crop of the Southern states, and fruits produced in almost every part of the country add greatly to the wealth of the nation.

SOME PRODUCTS OF A TYPICAL PLANT

(*Cotton*)

- Cotton seed
  - Staple for
    - Wadding
    - Batting
    - Stuffing materials for cushions, upholstery, horse collars, pads, etc.
    - Absorbent cotton
    - Felt
    - Artificial leather
    - Yarns — candle and lamp wick, twine, rope, carpets
    - Cellulose — artificial silk, writing paper, toilet articles, explosives
  - Hulls for
    - Feed
    - Fertilizer
    - Paper stock
    - Household utensils
    - Fiber for explosives
  - Cake and meal for
    - Dyestuffs
    - Fertilizer
    - Feed for cattle, poultry, swine, horses
    - Food — candy, flour : bread, cake, crackers
  - Oil
    - Yellow oil
      - Lard compound
      - Stearin
      - Butter oil
      - Salad oil
      - Butterine
      - Cooking oil
      - Packing sardines
    - Candles
    - Olive liquor
    - Cosmetics
    - Lubricating oil
    - Putty mixer
    - Paints
    - Tempering tools
    - Soap stock
      - Soap
      - Washing powder
      - Glycerol
      - Roofing tar
      - Paint
      - Dyestuffs

6. Protection of Farm Crops

439. Enemies of Farm Crops. — Insects, weeds, and disease are the chief enemies of our crops. Insects alone destroy, on the average, about $1,000,000,000 worth each year.

Plant diseases are numerous and hard to control. *Fungus* plants produce spores which grow thread-like masses called

Figure 277a. — Spraying Fruit Trees.

Why is such a process necessary? It must be done three times each season — once as the buds are about to open — once when the flowers are fertilized and the petals have fallen — once when the young fruit is formed. Explain.

mycelia (mī-sē′lĭ-*a*). These cling to the cultivated plant and drive sucking threads or *haustoria* (hôs-tō′rĭ-*a*) into the plant tissues, absorbing the sap and killing the plant. Potato scab, corn and oat smut, and wheat rust are all fungi. Bordeaux mixture sprayed upon potatoes will destroy the potato blight (Figs. 277a and 277b).

Grasshoppers, army worms, tent caterpillars, codling moths, boll weevils, and San Jose (săn hō-sā′) scale destroy

our crops. Their control depends upon (1) a knowledge of their life history; (2) knowing their natural food; (3) their natural enemies; and (4) what poison to give them. Lime sulphur used several times during a season destroys the codling moth caterpillar. Rotation of crops outwits the corn

FIGURE 277B. — SPRAYING TREES BY THE WHOLESALE.
What is the advantage of this method? What is the disadvantage?

worm. Paris green kills off the potato beetle, while plant lice can be best controlled by use of an oil emulsion.

440. A Crop Summary. — The total value of the garden products and farm crops of a recent year was $16,025,000,000, enough to pay off at once three-fifths of our national debt.

But the live stock fed by these crops was valued at $8,957,000,000 more, making a grand total value of all products of the soil in the United States of over $24,000,000,000, enough

to pay off our present national debt at one payment. [Study Plate IV (Key Picture 17).]

441. Agriculture and the Work of the World. — It is easily seen that agriculture is the leading and basic industry in the United States to-day. The preparation of the soil and the raising of crops and animals require a great amount of labor. The transference of crops and of animals and animal products is the chief source of revenue of the railroads of the country. The railroads make manufacturing industry possible. Food feeds the nation and gives it strength to work in shop, office, and factory. The very work of the world is dependent upon the soil. To know this and to appreciate it is worth the thought of everyone.

SUMMARY

Man's early existence in the world was very hard because of his great struggle to get food. With the development of his first crude tools he learned to stir up the soil and grow plants. For untold centuries the *tilling* of the soil has been the *fundamental industry* of man because the world must eat. Up to the middle of the 19th century, however, the *sickle* was used about as it was 2000 years ago.

In the United States *agriculture* (tilling of the fields) developed rapidly, because of the richness of the soil and the energy of the early settlers. Early *migrations* into the Mississippi Valley developed a great *central agricultural area* which to-day is the *granary* of the world. Successive migrations developed *special areas* for *special crops* adapted to those areas, as the *fruits* of *California* and *Florida* or the *wheat* of *Minnesota* and the *Dakotas*.

The farming of the great *western plains* is now carried on upon a gigantic scale with the use of *gang plows* and *tractors*, *seeders* and *drills*, *reapers* and *binders*, *threshers* and *bagging machines* — all of which do the work of thousands of men and make the feeding of our increasing population possible.

At the same time scientific experiments have shown the necessity and means by which the *soil* may be *renewed*, principally by the use of *fertilizers*, *clover planting*, *crop rotation*, *bacterial inoculation*, etc.

To *increase* the amount of *land* under *cultivation*, great *water projects* have been developed in the west to *store water* and then distribute it in *irrigation ditches* to *arid areas* which are rich in plant food but which *lack water* to make this food available for plant

growth. On the other hand, *swamp lands* in the south, rich in plant food, but lacking oxygen, are being *drained* and planted to fruits and other crops. Both schemes are adding thousands of acres to our sum total of tillable land every year. Finally, in the far edge of the central states where little irrigation is possible, and where long drouths are common, *dry farming* is being carried on to advantage, thus keeping water in the soil.

The *important farm crops* all over the country are *corn*, which leads all others in the number of bushels grown, *wheat*, *oats*, *hay*, *cotton*, and *fruits*. All these products are yearly attacked and destroyed by *insects*, *diseases*, *weeds*, etc. to the amount of over *$1,000,000,000*. *Agriculture* is the *greatest industry* in the *world* because it feeds men the world over and work cannot be done without food.

Remember that :

1. The earliest industry was the securing of food.
2. The early growth of the United States was due to the seeking of fertile soil for growing crops in the West.
3. Agriculture on a large scale began when improved farm machinery was produced.
4. Modern farming depends for its success upon a thorough knowledge of the best methods of soil improvement and crop control.
5. The wealth of this country depends primarily upon its soil. Its future prosperity will depend on how well the land is cultivated and how much of our swamps and desert land is reclaimed and put under intensive cultivation.

THOUGHT QUESTIONS

1. Why cannot one grow a plant in a pail of water?
2. Why is it sometimes better to feed farm crops to animals than sell them?
3. What effect does harrowing have upon the volume of air in the soil?
4. Name three ways in which legumes (beans, peas, etc.) benefit the farmer.
5. Why are young plants cut back when they are transplanted?
6. Mention three important ways of restoring fertility to the soil.
7. In farming, it is most important to keep down the weeds. Explain.

8. Some one has said that thorough tilling is as good as the use of manures and fertilizers. Explain.

9. Give at least two reasons why the greatest corn crops are produced in the Middle West.

10. Give reasons why the greatest meat-packing centers are in the city of Chicago.

11. Develop five good arguments for the conservation of our state and national forests.

SPECIAL PROBLEMS

1. Determine what ordinary soil requires to cause beans and corn to grow best.

a. If possible, prepare seven plots of soil each 2×4 feet. Secure 1 lb. of Sodium Nitrate. Call this *A*. Secure 2 lb. of Acid Phosphate. Call this *B*. Procure 1 lb. of Potassium Sulphate and 1 lb. of Lime. Call these *C* and *D* respectively.

b. In Plot 1 place no fertilizer; in Plot 2 put in a teaspoonful of *A* and *B*; in Plot 3 put in a teaspoonful of *B* and *C*; in Plot 4 put in a teaspoonful of *A*, *B*, *C*, *D*; in Plot 5 put in same amounts of *A* and *C*; in Plot 6 put in same amounts of *A*, *B* and *C*, and in Plot 7 put in same amounts of *A* and *D*.

c. Plant in each plot 50 pea seeds and 50 corn kernels. Compare crops in each plot to decide what fertilizer is most needed by the corn and peas in this soil, what combination of fertilizers is the best to grow these crops and what particular effect lime has on any crop.

2. Keep a record of the planting dates, dates of the first appearance of the seedlings, the first appearance of the flowers, the maturing of the fruits, the harvesting date, the yield, the cost of a given crop, the receipts and the profits on this crop.

3. Make a detailed study of the life histories of three typical farm crops (corn, wheat, potatoes).

4. Study the life history and the best methods of exterminating three typical insect pests on the farm (squash bug, corn borer, codling moth.)

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Austen. Electricity on the Farm. The Macmillan Co.
Burkett, Stevens, and Hill. Agriculture for Beginners. Ginn and Co.
Burns. Stories of Great Inventions. Harper and Bros.
Chamberlain. How We are Fed. The Macmillan Co.

Carpenter. How the World is Fed. American Book Co.
Carrier. The Beginning of Agriculture in the United States. McGraw.
Davis. Productive Plant Husbandry. J. B. Lippincott Co.
Davis. Productive Farming. J. B. Lippincott Co.
Gowin and Wheatley. Occupations. Ginn and Co.
Hall. Three Acres and Liberty. The Macmillan Co.
McMahon. Success in the Suburbs. G. P. Putnam's Sons.
Martin. Botany with Agricultural Applications. Wiley.
Price. The Land We Live In. Small, Maynard, and Co.
Rochelau. Great American Industries. A. Flanagan Co.
Rogers. Trees Worth Knowing. Doubleday, Page and Co.
Spellman. Farm Science. World Book Co.
Youmans. Pioneers of Science in America. D. Appleton and Co.

PART VI

Of all monarchs, Nature is the most just in enactment of laws — and the most rigorous in punishing the violation of them.
— Wilkins.

THE WORK AND CARE OF THE HUMAN BODY

From earliest times man was the principal source of energy in doing the work necessary to satisfy his needs of food and shelter. This work he did with his hands and by "the sweat of his brow." He struggled to get food to give him energy to do more work. He built a shelter and clothed his body to protect it so that it could work better and with less danger of being damaged by the elements. Man's body was an engine. It was the source of all power for all the early labors of man. To-day it controls the forces of nature that do work for us on a vast scale.

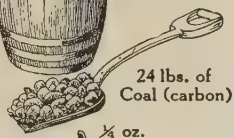
Food is fuel to the human engine. The source of this food is the green plant or the animal that feeds on the green plant. The human body is an ingenious machine for the using of food and the releasing of its stored energy in the form of bodily work. It is important that we know something about the structure and working of this wonderful engine. Engines must use the best fuel if they are to do the best work. It is, therefore, well to know what to feed the human engine and how to feed it.

Finally, the engineer of this body is the brain and nervous system. A good engineer must be trained. So must the nervous system be trained through the formation of good habits. Good habits conserve life, through the avoidance of risks and dangers, and build character and success. In Part VI you will discover how your body is fed, run, and controlled.

What Your Body Is Made Of

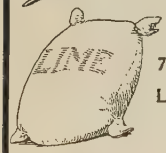
The Story Told in Pictures

10 gallons of water



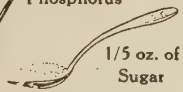
24 lbs. of Coal (carbon)

¼ oz. of Iron



7 lbs. of Lime

1.8 lbs of Phosphorus



1/5 oz. of Sugar

1.8 oz. of Salt

112 cu. ft. Oxygen; 60 cu. ft. Nitrogen; 561 cu. ft. Hydrogen

Iodine Equivalent to 1/10 of one drop of Tinct. of Iodine

and about 10 oz. of other elements, including potassium, fluorine, sulphur, and magnesium

The Same Story in Percentages

This picture illustrates what you would get if you analyzed the "contents" of an average man. These chemical constituents of the normal human body have a market value of about 98 cents! The column below shows the percentages by weight of the elements making up the various tissues, while on the opposite side of the picture are shown the normal quantities of each substance. Note that the body is mostly composed of water.

← 66% Water

← 3.1% Nitrogen

← 2.1% Hydrogen

← 15.8% Carbon

← 2.5% Calcium

← 1.2% Phosphorus

← 6.7% Oxygen

Besides the above elements the body contains minute quantities of salt, sugar, potassium, iron, sulphur, iodine, magnesium, and fluorine, totaling a fraction over four tenths of one per cent.

Popular Science Monthly.

KEY PICTURE 18.

CHAPTER XVIII

FOODS AS FUEL FOR THE HUMAN ENGINE

Every ounce of food, every physiological process, every mechanical action, in short, every bit of work is a transformed sunbeam. —*Wood.*

Do you know that your body is an engine? Give some reasons for so regarding your body. Do you know that the food you eat is a fuel? It makes you warm. You know that wood and coal give different amounts of heat when burned. So foods are of different values to the human engine. Do you know, then, how to buy fuel for your body? What do you know about a balanced diet? Did you ever hear of a mixed diet? You certainly have heard of vitamins. Every breakfast food now boasts of them. Does it make any difference to you how your mother prepares your food for you? What do you think pure foods are? What do you think adulterated foods are? Do you think alcohol a good thing to leave alone? Why?

Some Practical Questions :

1. Why is your body called an engine?
2. Make a list of the different foods you eat during one day. Determine the plant or animal from which each food came and report it to your class.
3. Were the foods you ate yesterday raw or cooked? If you used cooked foods, find out how they were put into proper form for eating (boiled, fried, broiled, baked, or stewed).
4. What has the sun to do with your dinner? Does the weather in any way affect what you have for breakfast? Do the movements of the earth determine what you have for lunch?

5. Make a list of ten raw foods, ten manufactured foods, and ten foods prepared in your own home. Tell how each is prepared for your use.

6. Show how your city or state food regulations are more important than weight regulations of fuels.

Home Problem. — Make a list of the foods on your table at dinner to-night. Find out the source of each kind on the table, where each was produced, how it was prepared for your use, and how it got to your table.

Field Problem. — Study the food stores on your way to and from school and determine how foods are offered for sale, how handled, and how wrapped up for the customer. Make suggestions for improvement. Comment on the good points you observe.

1. Foods as Transformed Sunbeams

442. Food and Work. — Without food no one can live long or do work any more than an engine can generate steam without coal. For this reason you ought to know the difference between good and poor fuels (food) for the body and how to secure and use the best. Like the engineer, you must also know something about the structure of the human engine in order to run it and care for it properly.

We may say, then, that the subject of foods is the most important in the whole field of general science, for without foods the work of the home, the factory, the railroad — in fact, all the work of the world — would have to stop. Where did all these foods really come from?

443. The Human Body and a Locomotive. — It is interesting to note that the human body somewhat resembles a steam locomotive. For example: (1) Both are composed of many parts which co-operate to make a unit of the whole mechanism; (2) both must be fed fuel (food and coal); (3) the sources of these fuels are the same (carbon dioxide and water, which were originally combined in the coal for the engine or in the bread for the body); (4) both carry on oxidation within their structures (the body in the cells, thus consuming itself; the engine in the firebox without consuming itself); (5) both produce carbon dioxide and water

as wastes; (6) both release heat energy; (7) both do work; (8) both wear out; (9) both need to be repaired (the body repairing itself and the engine being repaired by mechanics); (10) both need to be controlled (the engine by an engineer, the body by a brain within itself).

The body differs, however, in several respects from the engine. (1) It can repair itself; (2) it can grow; (3) it can move itself without outside help; (4) it, like all other living things, can produce others like itself; (5) the body is composed of organs which are fed by a life-giving fluid, the blood; (6) the body is controlled and its actions correlated by a nervous system; (7) the body has a brain which can think and will to act; (8) the body can heal itself; (9) the body has power of self-defense; (10) the body tries to fit itself to changing conditions (Key Picture 18).

444. Food Fuel Elements. — Would you suppose that common foods contain the same fuel elements you discovered in wood and coal, back in Chapter VIII? A simple experiment will give you an interesting bit of knowledge about foods.

Suggested Experiment. — If you get a piece of stale, hard bread or cracker, a piece of dried beef, a Brazil nut, some sugar, some dried boiled potato, some test tubes, a Bunsen burner, some limewater, and a knitting needle, you can make a discovery.

Place a piece of the bread in a test tube and hold over the flame. Note the change in color of the bread and observe what appears upon the sides of the tube. Do the same with the sugar, potato, and beef. They all turn black and give off water. Place the meat of the Brazil nut on the needle and hold in the flame. Note what happens and carefully examine the appearance of the nut as it burns. Hold the nut, after it begins to burn by itself, under the mouth of a clean, dry test tube. Examine, after a moment, the inner sides of the tube. Account for the soot and water there. Quickly pour some limewater in tube and shake. Result? Conclusion?

Do common foods contain the fuel elements? What are these elements? Is food a fuel? Explain. You may now begin to see why the human body is called an engine and why we eat foods.

2. The Nature of Some Common Foods

445. Food Tests. — How can you detect starch and sugar in your daily diet?

(Key) Demonstration 46: ***Problem: How can one detect the presence of starch and sugar in foods?***

Materials: Corn or potato starch; grape sugar; iodine solution; a Bunsen burner; Fehling's solution; a lemon; some bread; some boiled potato; and several test tubes (Fig. 278a).

Method: Place a little iodine upon some of the cornstarch. Note the reaction. The blue-black color is a sure test for starch. Place

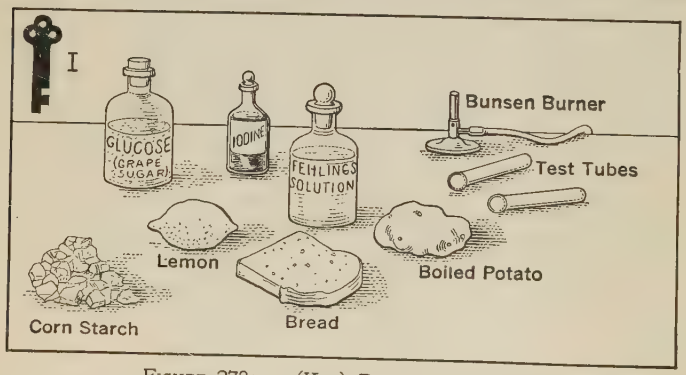


Figure 278a. — (Key) Demonstration 46.
What is the use of each labeled part of apparatus?

a small portion of the boiled potato in a test tube with water and heat over the flame until it begins to boil. Pour into the tube some of the iodine solution. Note the reaction. Place a few drops of the iodine upon the bread, and a few more drops on a small amount of lemon juice in a test tube. Record the results.

Place a piece of grape sugar the size of a pea seed in a test tube about one quarter full of water. Heat over the flame until the solution shows signs of boiling. Now pour in a small amount of Fehling's solution. Heat again. Note the changes in color and particularly observe the last color produced. This brick-red or terra cotta color is a sure test for grape and other simple sugars.

Now test some of the potato in water in a test tube with the Fehling's solution. Note the result and record it. Try the bread next. Finally, test a small amount of the lemon juice in the same way.

Observations: What is the test for starch? Was starch found in the bread? in the potato? in the lemon? In which was most found? What is the test for grape sugar? Was sugar found in the potato? in the bread? in the lemon? Would you expect to find sugar in a lemon? Why? Explain this.

Conclusion: How would you test foods for the presence of starch and grape sugar? Give full statements. Could you test other foods? Try it.

This is the most important demonstration in this chapter, so write it out most carefully in your Science Discovery Book.

(Key) Demonstration 47 : ***Problem: How can one detect the presence of fats and proteins in foods?***

Materials: Some olive oil; white of eggs; nitric acid; glazed paper; a Bunsen burner; test tubes; a piece of bacon; a Brazil nut; bread; household ammonia; and half of a small potato (Fig. 278b).

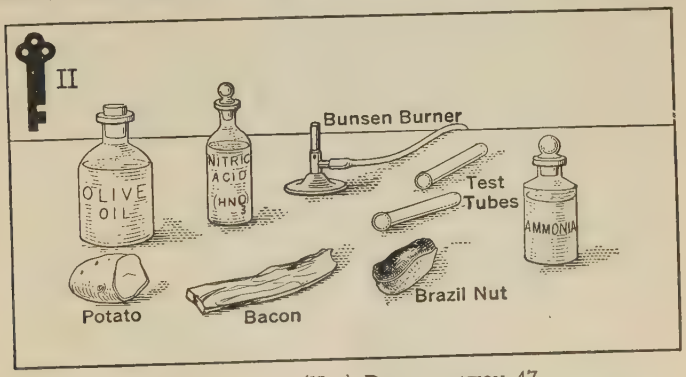


FIGURE 278B.—(KEY) DEMONSTRATION 47.

How is each bit of apparatus here shown used in the demonstration?

Method: Place some of the olive oil on the paper. Allow it to spread a little. Hold high over flame. Note the effect of the oil on the paper as you hold it up to the light. Oil always makes glazed paper semi-transparent. Rub the Brazil nut upon a dry part of the paper. Try the bread next. Finally test the piece of bacon in the same way. Note the relative results and record them.

Place some of the egg white in a test tube and pour in some of the nitric acid. Boil. Note the effect, and the final color of the egg white. Add enough ammonia to neutralize the acid. Note again the final color effect. This is a test for proteins (see section 447).

NOTE. — Burn any food; if the fumes given off remind you of burning leather or feathers, it contains proteins.

Now place some of the acid on the bread. Note the effect. Add a few drops of the household ammonia. Note the effect. Try the same tests with the bacon, the Brazil nut, and the potato, being sure that you get the chemicals on the skin of the potato as well as on its white part.

Observations: What effect does the oil have on the paper? Is there oil in the Brazil nut? in bread? in bacon? Do you think that a potato contains oil? What is the test for proteins? What effect does the ammonia have upon the egg white? Give the relative amounts of protein in bread, bacon, Brazil nut, and potato.

Conclusion: What are the tests for fats? for proteins? How would you test orange juice, beef, or syrup for proteins? Try these tests on some of the common foods in your home and report on them. Write this out in complete form in your Science Discovery Book.

The question now arises: Have you tested for the presence of every food substance? Can there still be other substances, in bread, for example, that your tests so far have not shown?

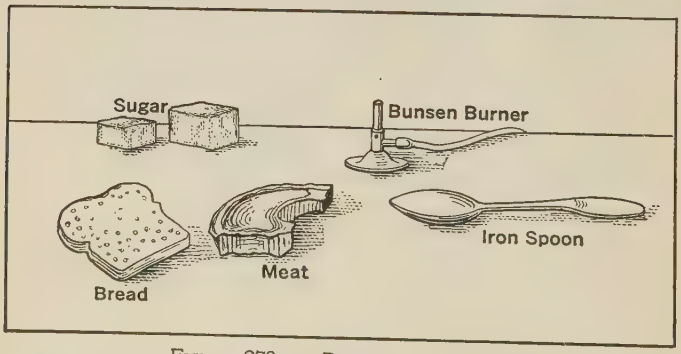


FIGURE 278c. — DEMONSTRATION 48.

What does each of the above foods contain? How do you know?

Demonstration 48: *Problem: Do foods contain minerals?*

Materials: Sugar; a small piece of beef; bread; an iron spoon; and a Bunsen burner (Fig. 278c).

Method: Place the sugar in the spoon and hold over the flame. Note what happens. Hold in position until there is no more burning. Remove what is left and place on a piece of paper. Now

place the meat in the spoon and treat in the same way. Finally, treat the bread in the same manner.

Observations: What happened to the three foods? Did any one disappear entirely? Why did they not all completely burn? What was left? What is the nature of ashes? What is the appearance of these ashes?

Conclusion: Do foods contain minerals? What have you observed to be the nature of these minerals?

Practical Applications: Of what value are minerals to the human engine?

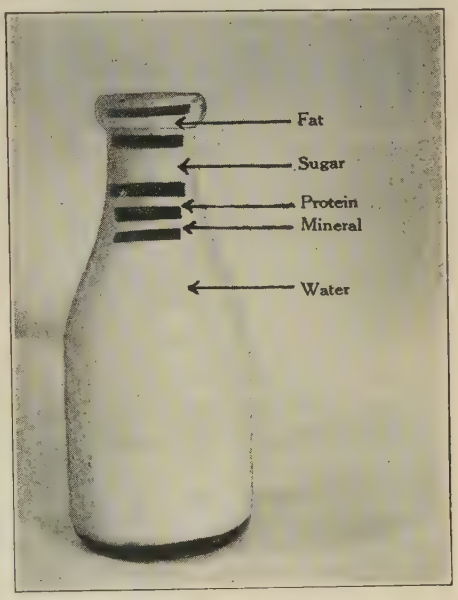


FIGURE 279. — THE FOOD VALUE OF A BOTTLE OF MILK.

The space between the blank labels indicates the amount of each nutrient. What forms the greater part of milk? Why is milk often called the perfect food?

3. FOODS AS FUEL

446. Food Is Fuel. — Butter will burn fiercely if held in a spoon over a Bunsen flame. Sugar will burn readily on the top of a hot stove or in a kettle. In each case we are aware of the presence of carbon. How? Since all fuels are composed of organic substances and carbon is a fuel element in all fuels, it follows that butter, sugar, bread, meat, and like foods are all fuels. Some foods are, of course, better fuels than others, just as coal is a better fuel than wood or peat.

447. Foods Differ. — Foods are different in *composition*, in their *use* to the human engine, and in their *heat values*. *Protein* (prō′tē-ĭn), a substance very closely resembling egg white, *starch*, *sugar*, which is classed with starch under

FIGURE 280A. — CARBOHYDRATE FOODS.

Name them. What nutrients do these foods contain in abundance? Of what value are they to the body?

the name *carbohydrate* (kär′bō-hī′drāt), and *fats* are all found in large amounts in the things we eat. Finally, there are certain substances like salt, calcium, water, magnesium, and sodium, which are found in the foods we eat, but will not burn. These are called *inorganic foods*, or minerals. Why? The uses of the different fuels to the body are summarized below. They should be thoroughly understood.

NUTRIENTS	USES
Proteins (egg white, milk curd, wheat gluten, lean meat, peas, beans, cheese).	Build tissues; repair tissues (cells, muscle, tendons).
Fats (fat of butter, meat, oils, wheat, nuts, pork)	Form fat tissues, serve as fuel, and release much energy.
Carbohydrates (sugar and starch; in fruits, potatoes, bread, candy) transformed into fats.	All serve as *fuel* and release *energy* in the form of heat and bodily power by which the body is able to do work.
Mineral matter (ash) Compounds of lime, potash, soda, etc.	Used in making bone and teeth, aids in digestion, absorption, circulation, excretion, and respiration.
	Water is used to help dissolve foods, form digestive juices, carry foods to and wastes from the cells, and in oxidation; it actually forms a part of all protoplasm.

NOTE. — Vitamins are essential as *body regulators* (see section 455).

448. Heat Values of Foods. — In our discussion of fuels, a unit of heat was determined upon called the *Calorie*.

The Calorie is the amount of heat necessary to raise one pound of water 4° F. in temperature.

When applied to foods, it was found, for instance, that a pound of butter will release 3600 Calories of heat when burned in a bomb calorimeter. This means that the heat given off by burning a pound of butter would be enough to raise 1800 quarts or nearly 2 tons of water 4° F. Yet, hard-working men, such as coal heavers and hod carriers, need to eat enough food each day to release more heat than this, if they are to do their work. By careful experiments it was found that a gram of pure fat will release 9.3 C. (Calories), a gram of carbohydrate (starch, sugar) 4.1 C., and a gram of protein 4.1 C.[1]

FIGURE 280B. — FATTY FOODS.

Name them. How do you know that these foods contain fats? How are fats of value to the body?

FIGURE 280C. — PROTEIN FOODS.

Name them. These build muscle. What persons need these foods most? Most people eat too much of these foods. Why?

[1] To change grams into ounces and pounds when dealing with Calories, use the following table:

	Calories in one gram.	*Calories in one pound.*
Fats	9.3	4219
Carbohydrates	4.1	1860
Proteins	4.1	1860

Thus, there are about 263 Calories in one ounce of fat; about 116 Calories in one ounce of carbohydrates or one ounce of proteins. If one gram = .035 ounce, 100 grams = 3.5 ounces. One gram of fats = 9.3 Calories, 100 grams = 930 Calories.

4. What Foods the Human Engine Needs

449. Food Requirements of the Human Engine. — Very young children require much less food than older children and adults. Growing boys and girls at the ages of 12 to 16 require relatively more food than adults, while old people require less food than middle-aged people. Explain.

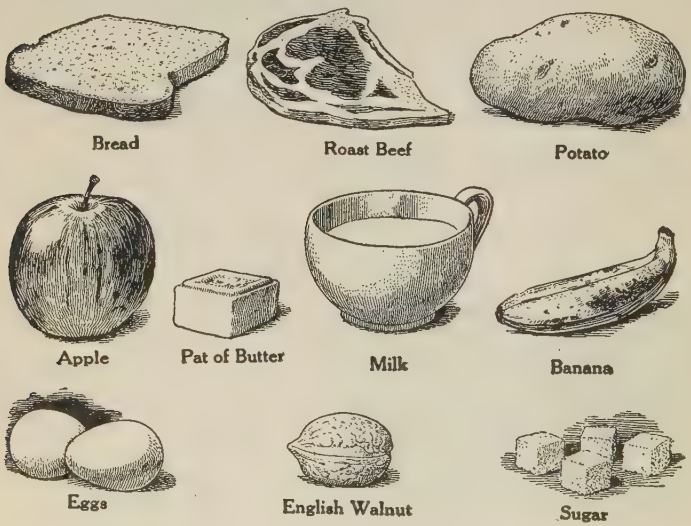


Figure 281. — 100-Calorie Portions of Food.

Every portion of food here contains about the same amount of heat energy. You need but 400 Calories for breakfast. Pick out your breakfast from this list. Do you ordinarily eat more or less than you need? Explain.

Boys require more food than girls of the same age, because they are more active. Men have, in general, larger bodies than women, they lose more heat and thus require more food. Explain. Again, the average man uses up more energy than the average woman because his work calls generally for more muscular activity.

A bookkeeper needs far less fuel than a ditch digger or a lumberman. Explain. The outdoor worker usually has

a better appetite than the clerk. Explain. The steel worker always needs more food than the manager of the mill. This food should be chiefly muscle-building and rich in fats. The manager does not need the same diet. Why?

Finally, environment makes a decided difference in the number of Calories needed. We all naturally eat more fats in winter than in summer. We crave these fats in winter and dislike them in hot weather. Again, the man working in a Canadian fur-trading post will need much more food than the man paddling a canoe on the Amazon River. Explain. Besides, the kinds of food used by the two men will be widely different. Meats will form a large part of the fur trader's food, while fruits and vegetables will feed the South American native. Explain.

450. Fuel Value Requirements of the Human Engine. — Experiments performed by scientists show that a person at rest, doing no actual work, requires 12 Calories of heat each day for each pound of his weight or .5 C. a pound an hour. For a man weighing 150 pounds, the heat requirement would be 75 C. an hour or 1800 C. a day.

For boys and girls in high school the following table should be interesting:

1.	14 years of age	24 C. a pound	?
2.	15 years of age	22 C. a pound	?
3.	16 years of age	20 C. a pound	?
4.	17 years of age	18 C. a pound	?
5.	18 years of age	17 C. a pound	?

For a boy or girl 16 years of age, weighing 120 pounds:

Sleeping (9 hours)	$9 \times .5 \times 120 =$	540 C.
School work and study (8 hours) . . .	$8 \times .75 \times 120 =$	720 C.
Studying (3 hours)	$3 \times .6 \times 120 =$	216 C.
Recreation, light work (4 hours) . . .	$4 \times 2 \times 120 =$	960 C.
	Total	2436 C.

According to the above table a boy 16 years of age needing 20 C. a day and weighing 120 pounds will need just exactly

2400 C. of heat in a day. Note that a boy 14 years of age will need 4 C. more a pound. Why?

451. How to Select Your Diet. — With a standard of $2\frac{1}{2}$ ounces of protein a day and a total of 20 ounces of food giving a total of 2800 Calories a day, how can you know that you are eating the proper amount of food with the right proportion of nutrients? A rough way to determine this point is to take your own weight as a basis. For example: If you weigh 160 pounds, you should eat approximately 80 grams of protein. Since the ratio of protein to the other nutrients is 1 : 8 you would eat 8×80 or 640 grams or 21.3 ounces a day. Another method is to trust to your own appetite. This latter method is all right *provided that you thoroughly chew your food.* The great danger is that you will eat too much protein and too little fat. The last and best method is the proper use of food tables.

5. How to Make Your Own Dietary

452. Food Tables. — Any person can make up for one day the amount and kinds of food used in the average servings. A sample diet for one day is given here based upon an allowance of about 75 grams of protein and a total of 2803 Calories for a day. Any menu coming close to this will not cause you to run any danger of eating too little or too much.

Breakfast

	Weight (grams)	Protein Weight (grams)	Calories
2 eggs	114	15.6	100
2 slices brown bread	86	4.4	200
1 portion cream of wheat	140	3.1	100
1 glass milk	225	6.8	160
1 lump sugar	8	—	33
$1\frac{1}{2}$ pat butter	29	.3	150
	602	30.2	743

	Weight (grams)	Protein Weight (grams)	Calories
Lunch			
1 plate bean soup	150	4.8	100
2 slices bread (brown)	86	4.4	200
1½ pat butter	29	.3	150
1 glass milk	225	6.8	160
1 orange	270	1.6	100
1 piece chocolate cake	55	3.4	200
	815	21.3	910
Dinner			
2 large chops	54	17.0	300
1 dish onions	120	1.2	50
1 potato	102	2.5	100
2 slices bread (brown)	86	4.4	200
1 pat butter	19	.2	100
1 piece of pie	100	4.4	200
1 apple	103	1.0	100
1 orange	270	1.6	100
	854	32.3	1150
Totals for the day	2271	83.8	2803

453. A Balanced Diet. — The need of a proper balance between the different nutrients is seen, when you remember that (1) the amount of protein needed is determined by the kind of work in which a person is engaged; (2) the fats and carbohydrates needed vary in amount according to such factors as the intensity of work, the kind of climate, and the seasons; (3) eating too much of one kind of food in order to secure the proper amount of nutrient from it throws too heavy a burden upon the various organs used in the digesting of this nutrient.

454. A Mixed Diet. — For the very young child, milk alone is a mixed as well as a balanced diet, because it contains almost the proper ratio between the nutrients and vitamins, plus a small amount of lime, phosphorus, and other elements, so necessary for bone and teeth building. Bread and butter contain all the essential nutrients for the growing child or the adult. Meats, peas, beans, and the like give us most of

our proteins, but no one wants to live on them alone. Vegetables furnish us with most of our carbohydrates, but there is an enormous waste in vegetables and much of their content is indigestible. But as valuable foods they are indispensable.

The mixing of the diet cannot, therefore, be overemphasized. Even among the proteins themselves there should be a great variety. Beans, meat, eggs, cheese, lentils, and breads all contribute different kinds and amounts

U. S. Dept. of Agriculture.

FIGURE 282. — A DAY'S RATION FOR A FAMILY OF FIVE PERSONS.

List the articles here shown. Is this a mixed diet? A balanced diet? Are vitamins found here? Why is this selection good?

of nutrients. From these the body may select its own building blocks with which it can build the different tissues of the body. Variety, then, in all kinds of foods is what the body is craving. It is for you to furnish this variety of food, always keeping in mind the proper proportion of each nutrient or the ratio of 1 : 3 : 6.[1] Indeed, one of the greatest contributions the mother can make to-day to the success of the

[1] The ratio between the number of Calories needed from the different foods would be about as follows:

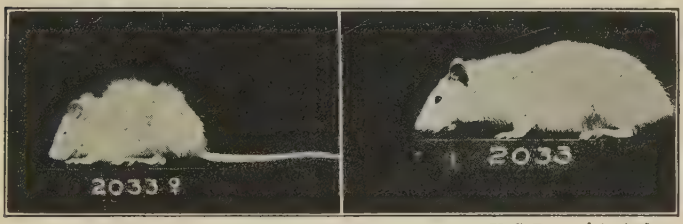
Proteins	Fats	Carbohydrates
1	3	5–6

The ratio in weight, however, would be somewhat different:

Proteins	Fats	Carbohydrates
1	1	4–5

home and family is to become an expert in the selection and purchase of foods and in the formation of proper dietaries for the family.

455. Vitamins. — Vitamins are a food element just recently discovered which serve as body regulators for growth and other life activities. They occur in foods in very small amounts, but are very necessary to man. The absence of a very small amount in the diet means loss of appetite, disease, and death. The German submarine



U. S. Dept. of Agriculture.

FIGURE 283. — HOW DIET AFFECTS LIVING THINGS.

The rat at the left was fed too small an amount of food, which also had too few vitamins. At the right is the same rat five months later. What do you suppose made the difference? What is the lesson here for you?

Deutschland was forced to put in at an American port during the World War because her entire crew had the scurvy, a disease due to the lack of green vegetables. Tomatoes, carrots, potatoes, oranges, and lemons are rich in the vitamin which prevents scurvy. There are several kinds of vitamins. Vitamin A (fat-soluble A, found in green leaves, tomatoes, cream, butter, cod liver oil, egg yolk) is believed to be a preventative of certain diseases of the eye. Vitamin B (water-soluble B, found in beans, peas, eggs, liver, and all cereals) prevents or cures *beri-beri*, a disease that causes pain in the limbs and swelling of parts of the body. Rye and whole wheat bread are rich in this vitamin. Lack of Vitamin B causes a loss of appetite. Vitamin C (found in oranges, cabbage, turnips, lettuce, watercress,

raspberries, tomatoes, fresh meat, carrots, and potatoes) prevents *scurvy* and *pellagra*. Limes, lemons, tomatoes, and pineapples are especially rich in this vitamin. The recently discovered Vitamin D is perhaps the greatest factor in the prevention of rickets. No family should ever be without oranges if health is valued among its members. Modern methods of canning fruit and vegetables help to make it possible to obtain at all seasons the vitamins necessary for health.

Below is a specimen diet for one day which will include the foods necessary to give you the required vitamins. Note it carefully and see if you are getting these vitamins in your daily diet. Study this with your mother.

1. Milk — one quart. One pint for an adult.
2. Vegetables — two daily.
3. Fruits — once daily.
4. Meat, fish, eggs, cheese, lentils, or beans.
5. Bread or cereals — preferably whole wheat bread or other entire grain.
6. Fat — butter or other fat in some form every day.

456. How to Balance and Mix Your Diet. — The problem of successfully fueling the human engine is not an easy one. Any good food table will help you make up your daily diet for a week. A different menu can be made from it for each day, thus giving needed variety. Foods left over from one day may well be served in a different way or in combination with others on the following day, thus making for economy. Suggest such a scheme to your mother, help her make up such a schedule, prepare a menu for each day for a week with her help, and try it for the purpose of seeing if (1) the food costs less, (2) there is an increase in efficiency, (3) there is less food waste than formerly. In preparing the daily menu let each serving equal about 100 Calories in value. It is this selection of food upon the 100-Calorie basis that should make the selection of a daily menu an easy matter.

457. Cost of Foods. — Many people think that the more a food costs, the greater its nutritive value must be. This is a great error. Five cents' worth of sandwich will give as

much energy or power to do work as 90 cents' worth of oysters. Below is a table giving a comparison of the cost of certain foods on a 100-Calorie basis.

Milk @ 15 cents a quart	100 Calories will cost $.024
Corn meal @ 10 cents a pound	100 Calories will cost $.0062
Cheese @ 40 cents a pound	100 Calories will cost $.02
Sirloin steak @ 50 cents a pound	100 Calories will cost $.044
Oysters @ 3 cents each	100 Calories will cost $.36

To make just one comparison will give you a contrast that will be remembered. 100 Calories of oysters cost $.36 as compared with $.0062 for corn meal. This is the same as saying that the oysters cost 60 times as much as the corn meal, assuming that both have the same nutritive value. This is an illustration of the fact that cereals and concentrated animal foods are better than other varieties both from the standpoint of nutritive value and cost.

6. Pure Foods and Their Preparation for Use

458. Cooking of Foods and Waste. — Much food is lost or wasted in the average kitchen. Food containing much bone or stringy material is a loss in most cases. Potatoes are often pared too deeply and the parings, which contain a highly nutritive part of the whole vegetable, are thrown away. Baked potato skins, when thoroughly scrubbed, are palatable and very nutritious. Why? Bones can be saved and when used in soups and stews make excellent foods. The cheaper cuts of meat are tender, if properly and thoroughly cooked. Rejecting the water after cooking vegetables in it results in the loss of some of the soluble vitamins (B and C). Minerals also are lost. Boiled, roasted, or steamed foods are more easily digested than fried food. Raw eggs and oysters are digested in half an hour. Hard-boiled eggs may take four hours to digest. Meats should be brought slowly to a boil if it is desired to drive the nutrients out into a stew or soup. If the meat itself is to be eaten, it should be *seared* in the

oven before boiling, or put into water that is already boiling. This sudden heat causes a hardening of the outer protein which keeps the nutrients from being boiled out.

459. Digestibility of Foods. — In general, animal foods are more easily digested (if properly cooked) than vegetable tissues, because the latter have so many woody cells which cannot be digested. Cereals, starchy fruits, peas, and beans are, on the whole, less digestible than fish and dairy products because the nutrients are so concentrated. Again, foods which contain too much "roughage" or vegetable fiber are positively injurious to some people, although they prevent constipation. Certain acid fruits like strawberries may produce irritation in the digestive tracts of some people. They may even cause the mouth to become sore and a red rash to break out upon the body. Digestibility of foods may be an individual matter and foods should be purchased which will most nearly suit the needs of the whole family.

460. The Best Food. — So many people ask: "What, then, is the best food to eat, anyway?" That is a hard question to answer, because "what is one man's meat is another man's poison." However, from what has already been said, it will be safe for you to conclude that *the best food is that which gives the greatest amount of nourishment and energy at the least cost, with the least waste, and at the same time agrees with the person who eats it.*

461. Adulteration of Foods. — The invention of the tin can as a sealed container made it possible to preserve foods so that they are available in winter almost as fresh as when picked. To make doubly sure of the preservation of these foods salt, sugar, vinegar, smoke, and spices used in moderate quantities for this purpose are harmless. Unscrupulous packers have sometimes been guilty, however, of canning foods which were partially spoiled when put into the cans. To cover or disguise this putrefaction and prevent further spoiling, certain chemicals such as alum, borax, boracic acid, benzoic acid, sulphates, formaldehyde, and benzoate of soda

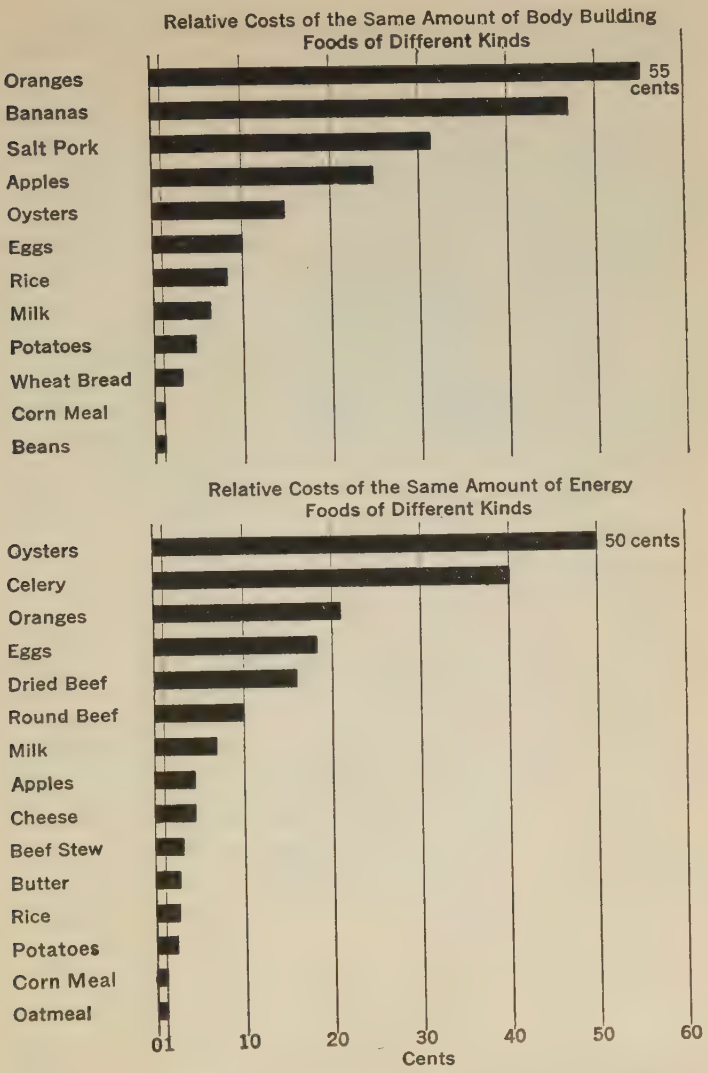


FIGURE 284. — COSTS OF BODY-BUILDING AND ENERGY-RELEASING FOODS. List the least expensive body-building foods. Explain this. Why are potatoes, corn meal, beans, etc., fed to lumbermen?

are used. Such foods are not fit for use and for this reason are said to be *adulterated.*

Many times something is added to foods to increase their bulk or weight and incidentally reduce the food value. Water is thus put into milk, and chicory in coffee. This practice makes money for the man who follows it at the expense of the consumer, both in pocketbook and in health.

Another method of adulterating foods is the removal of some valuable product from them and selling it. Oil is expressed (pressed out) from olives and sold separately, but the consumer who buys the olives thinks he is getting the oil also. Cream is removed from milk.

Still another method is that of substituting one inferior food for a superior food. In this way oleomargarine is sold for butter, chicory for coffee, and glucose for cane sugar in candy. Dyes and other bright colors are put into candy and meats to freshen them and make them attractive. Such dyes are coal-tar products and are considered harmful. Glue, shellac, lampblack, and copper are also used to give candy a better appearance or to prevent its melting in warm weather.

Demonstration 49: ***Problem: How can the adulteration of some foods be detected?***

Materials: Ground coffee; a glass of cold water; a beaker; hydrochloric acid; a new iron nail; a pan of water; a Bunsen burner; an iron tripod; a can of peas; butter; a spoon; table salt; and a small battery jar.

Method: A. (Adulterated coffee.) Spread a half teaspoonful of the coffee over the water in the glass. Leave it for five minutes.

B. (Copper in canned goods.) Put into the beaker a teaspoonful of mashed peas, two teaspoonfuls of water, 20 drops of hydrochloric acid, and the iron nail. Set the beaker in the pan of water and boil the water in the pan for 10 minutes, meanwhile stirring the mixture.

C. (Butter.) Place a small piece of butter in the spoon and hold it over the Bunsen flame.

Observations: Does the coffee float or sink? If it sinks leaving a brownish streak in the water, it is chicory. If it floats, it is coffee. Does the nail turn copper colored? If so, copper salt is present to make the peas look fresh and green. If it is good butter, it will foam much and boil quietly; if not, it will sputter and produce little foam.

Conclusion: Write out in full how you would test for adulterations of coffee, canned goods, and butter.

462. Pure Food Laws. — Food adulteration is now largely controlled by the national Pure Foods and Drugs Act passed by Congress in 1906. Under this law, foods can still be preserved with harmless adulterants, but the use and amount of such must be indicated on the label of the container, or the food must be guaranteed to be pure and registered under the law with the correct weight of the contents indicated. How, then, does the law protect the consumer? It all depends upon the consumer as to how much he will be protected. If he can read English and wants pure food, he can have it by reading the labels on the canned or bottled goods he buys. If they are not pure, he can refuse to accept them and can generally get the pure article from the same dealer by paying a few cents more for it.

FIGURE 285A. — SOME PURE FOODS.

Every article here is guaranteed as being pure. How can it be proved that the guarantee is true? How can you know what foods are pure as you buy them?

463. Stimulants. — Substances such as tea and coffee cause a slight increase in the bodily activities and for this reason are called *stimulants*. Children should refrain from frequent use of them, especially of coffee. Cocoa, it must be said, has food values, as it contains 21% proteins, 30% to 50% fats, and 30% carbohydrates.

The stimulant of greatest importance is *alcohol*. Claimed by some to be a food, it is nevertheless a very poor food, releasing only heat and that temporarily. It cannot build tissues. It interferes with the proper working of the body organs and it overtaxes the heart. It creates very often a dangerous habit which can scarcely be broken. It has a

liking for water which it draws out of the digestive juices. It interferes with digestion. It coagulates albumen (ăl-bū′mĕn) and hardens the body cells and artery walls. It often results in apoplexy (ăp′ŏ-plĕk′sĭ), Bright's disease, heart failure, rheumatism, and other kindred diseases. *Alcohol is a deadly poison.*

Insurance companies well know its effects upon the expectancy of life. Roughly speaking, the regular user of alcohol may expect to live 15 years less than the total abstainer.

Again, alcohol undermines and breaks down the *will power*. It enslaves one as a drug. It leaves the user of it weak while food strengthens him. It lessens muscular power while food increases it. It lessens the power to endure cold while food strengthens it. Admiral Peary attributed his final victory in discovering the North Pole to the elimination of alcohol from the diet of his crew and to the substitution of tea on all sledge trips.

464. Drugs and Patent Medicines. — Many persons are very careless in selecting their medicines. Dishonest manufacturers, knowing this, sell, at a large profit, large quantities of medicines containing considerable amounts of drugs or stimulants. The relief such medicines give is usually only temporary and often the results are actually bad, causing further sickness rather than remedying the original trouble. Practically all such medicines are patented. There are, however, some very excellent patent medicines which many competent physicians feel justified in prescribing. When you require medicinal treatment, the sensible thing to do is to have a reliable physician prescribe what such treatment shall be.

The subject of this section is interestingly treated in several books. Through your local library locate such a book and prepare a review of it for class report. One such book is "The Great American Fraud," published by the American Medical Association, Chicago, Illinois.

SUMMARY

The human body is an engine: it needs fuel, burns this fuel, gives off wastes, releases heat, and does work just like an engine. It differs from an engine in some very important ways, the principal one being that it is *alive*.

Its efficiency as an engine depends upon a very careful use of fuel (food). In the human body it is essential that we know how to feed it and when to feed it.

Fuel for the human engine consists of foods of four principal kinds: *proteins*, *carbohydrates* (*starch and sugar*), *fats*, and *mineral matter*. All differ in their composition, fuel values, and use to the body. The fats and carbohydrates release large amounts of heat energy, the proteins release heat and build tissues, while the minerals help in carrying on body processes and in building bone.

The *unit of measure* of the fuels used by the body is the *Calorie*. The number of Calories required for the body each day depends upon age, sex (to a limited extent), climate, season, occupation, and time of day.

The *dietary* of any person is based upon a nutritive ratio of 1 : 3 : 6 for proteins, fats, and carbohydrates respectively. The work of selecting a dietary with the proper nutritive ratio is of the greatest importance. It should be *mixed* and *balanced*, because a mixed diet gives variety and secures to the body the vitamins so essential to our life processes, while a balanced diet secures a proper proportion of nutrients so that too much work will not be thrown on any one part of the body.

In buying foods, the cost, heat values, and the amount of waste in them should always be taken into careful consideration, as well as the nutritive value. *In cooking foods*, the palatability and digestibility of the prepared food must be considered. *The best food, in the long run, is that which gives the most nutritive value at the least cost and with the least waste, and best agrees with the consumer.* In buying foods, inferior and adulterated foods should always be avoided.

Alcoholic stimulants, *drugs*, and *patent medicines* should not be used except on advice of a reliable physician.

Remember that :

1. The human body is an engine.
2. Food is fuel for the human engine.
3. Food differs in its fuel value.

4. The dietary must be adapted to the kind of work the human engine does.

5. Stimulants and narcotics seriously interfere with the work of the human engine.

THOUGHT QUESTIONS

1. Why do hospitals and sanatoriums employ dietitians?

2. If a man feeds a horse oats for one week and hay for another week, on which kind of diet will the horse do the best work? Explain.

3. Is it possible for a man to live on bread and water alone? Explain.

4. "An apple a day keeps the doctor away." Explain this statement.

5. Fruit and vegetables should be a part of our daily diet. Why?

6. If a person is over weight, what foods should be used sparingly? if under weight, what foods should he learn to use?

7. Test some of the common foods used by your mother in order to determine the nutrients they contain.

8. Learn how to bake a loaf of bread. Report to the class on your work.

9. Learn how to prepare a dinner. Report your work to the class.

10. Make a study and report upon some important parts of the book entitled "The Great American Fraud," published by the American Medical Association, Chicago, Illinois.

11. Make some tests on foods for preservatives.

12. Learn the principal provisions of the Pure Foods and Drug Law of 1906, giving reasons for each part of the law.

13. Explain several dangers of using patent medicines.

14. Why do we choose a variety of foods?

15. What is meant by "one man's meat may be another man's poison"?

16. Criticize this dinner: Bean soup, roast beef, baked beans, peas, tuna fish salad, bread and butter.

SPECIAL PROBLEMS

1. Determine the nutrients in some of the common foods used in your home.

a. Make a list of the common foods used in your home for one day.

b. Choose from this list 1 dry food, 1 fruit, 1 cereal and 1 meat.

c. Make tests for each of the nutrients in each of the four types of foods selected. Record your results, indicating the amount of

each nutrient by a minus sign, if none is present, by a plus sign if some is present and by a double plus sign if much is found.

d. Now try to group all the rest of the foods in your list under some one of the nutrients you have tested. Test those in which there is much doubt. Verify your list by studying the tables of foods composition in any textbook.

2. Have all the members of your class fill out the score card, pages 556 and 557, and add up their total scores. Pick up any 12 score cards in the class and determine the average score for the 12. Is this average a poor, fair, or excellent one? Next note the items which bring the lowest score in most of the score cards. Find out the reasons for their low scores. Start a campaign in your class for raising the scores of all the members.

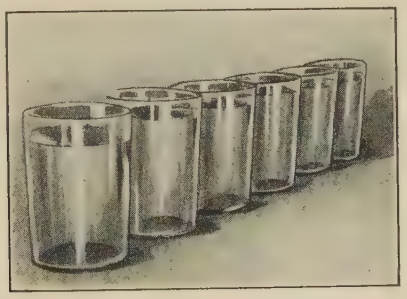


FIGURE 285B. — SOME PURE DRINKS.

Six glasses of pure water each day make for good health.

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Anderson. Starch and Starch Products. Pitman.
Bailey. Food Products: Sources, Chemistry and Use. Blakiston.
Bassett. The Story of Sugar. Penn Publishing Co.
Fisher and Fish. How To Live. Funk and Wagnalls Co.
Goudiss. Eating Vitamins. Funk and Wagnalls Co.
Hart. Leavening Agents. Chemical Publishing Co.
Hawk. What We Eat and What Happens to It. Harper and Bros.
Monaghan. What to Eat and How to Prepare It. George H. Doran Co.
Rexford. A One-Portion Food Table. Rexford.
Wellman. Food Planning and Preparation. J. B. Lippincott Co.

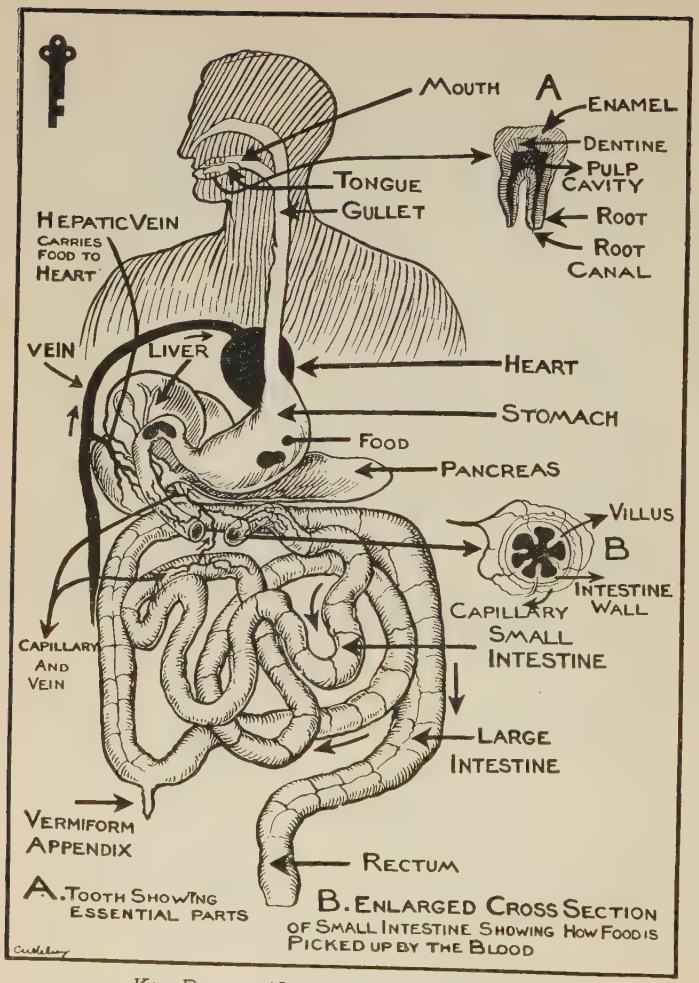
SCORE CARD FOR HYGIENIC LIVING

Read over carefully the score card below and if you can truthfully credit yourself with 75 out of the possible 100 credits, you are doing *fairly well;* if you can credit yourself with 85 credits you are doing *excellently;* if you can earn 90 credits you are *first-class.* Where do you stand? Whatever you have to omit in your scoring, you should at once begin practice upon in order that you may increase your *general health and efficiency.*

SCORE CARD	*Credits*	*Check*
1. Sleeping in the open or with bedroom windows wide open (screened in summer).	10	
2. Use of mattress with no feathers.	1	
3. Small pillow.	1	
4. Bed clothing aired daily.	1	
5. Rising regularly at 7 A.M. or earlier.	2	
6. Light exercise on rising (five minutes).	2	
7. Cold bath (unless ill).	3	
8. Hair brushed (25 strokes or more).	2	
9. Teeth cleaned (morning and night).	5	
10. Individual towel.	2	
11. Glass of water on rising.	1	
12. Hygienic breakfast — THOROUGH CHEWING. At least one item from each of three classes of food. Class 1, Fruit. Class 2, Bread, cereal, baked potatoes. Class 3, Eggs, bacon, milk, fish, cheese. A glass of water.	3	
13. No candy or other food between meals.	4	
14. No active exercise for 30 minutes after a meal.	3	
15. Carry books at arm's length and change hands often.	1	
16. Get best possible light at school.	2	
17. Use fully 20 minutes for lunch (not 5 eating and 15 running).	3	
18. Hygienic lunch — THOROUGH CHEWING. At least one item from each of two classes of food. Class 1, Bread, butter, crackers. Class 2, Milk, soup, cold meat.	5	
19. Two glasses of water in afternoon.	2	
20. Vigorous exercise (tennis, running, etc.) 30 minutes.	5	

Score Card Continued	*Credits*	*Check*
21. Rest 20 minutes before dinner.	1	
22. Hygienic dinner — THOROUGH CHEWING. Attractive table — 1; chew well — 2; eat moderately — 3; at least one item from each of three classes of food: Class 1, Potatoes, bread, macaroni, rice; Class 2, Soup, stew, roast, baked beans, cheese; Class 3, Fruit, vegetables. A glass of water.	10	
23. Study 2 hours.	2	
24. Sufficient light placed behind and above.	2	
25. Light exercise before retiring.	2	
26. Retire regularly by 9.30 P.M.	10	
27. Glass of water before retiring.	2	
28. Clean hands, face, and teeth before retiring.	2	
29. Hygienic clothing.	2	
30. Correct posture.	3	
31. Hands and finger nails kept clean.	3	
32. All meals at regular hours (not to vary more than 1 hour).	2	
	100	

Deduct 2 credits for the use of coffee or tea.
Deduct 20 credits for the use of alcohol or tobacco.



KEY PICTURE 19. — OUR DIGESTIVE SYSTEM.

Trace a bit of food (bread or meat) from the mouth to the rectum. Tell of its adventures. Find out the function of each labeled part. Show the connection between this system and the circulatory system (see Plate V). Why is the tooth given a prominent place here?

CHAPTER XIX

THE USE OF FUELS BY THE HUMAN ENGINE

So in descending streams, the silver chyle
Streaks with white clouds the golden floods of bile;
Through each nice valve the mingling currents glide,
Join their fine rills and swell the sanguine tide;
Each countless cell, a viewless fibre seek,
Nerve the strong arm and tinge the blushing cheek.
—Dr. Darwin.

You know that a locomotive must have a fire-box to hold the fuel. How are you built to use fuels? Did you know that all fuels for your engine must be prepared before they can be used? Do you know what happens to them? Do you know how foods and oxygen get to a cell in your ear or hand? If you cut yourself what happens? You lose some of the carrier of the foods. How would you stop this loss of blood? When the engine burns coal, ashes are formed, gases are given off, and water goes out the smokestack. How does your body engine get rid of its wastes and where do they leave the body? Have you a very good set of teeth? It is to be hoped that you have, because the teeth are the foundation of your health. Do you know why this is so? Can you tell some of the things that aid your body and some of the things that tend to make your body weak?

Some Practical Questions :

1. What is the effect of putting too much coal in the furnace?
2. What is the effect of leaving too many ashes in the ash pit?
3. Why are too much food and too much waste injurious to the body?

4. What are all the things that an engineer must do to keep his engine in working order? Show how the same things must be done to keep the human engine in good working order.

5. In what respects is the mouth a very important part of the digestive system?

6. Why do you often become hungry after much exercise?

1. The Digestion of Foods (Fuels)

465. How the Human Engine Prepares Its Fuel. — Fuels burn with different rates of speed and have different heat values. The same is true of foods. But regardless of these facts, practically all foods have to be prepared by the body before they can be used by it or become a part of it. What changes, then, are necessary before food can be burned in the human engine?

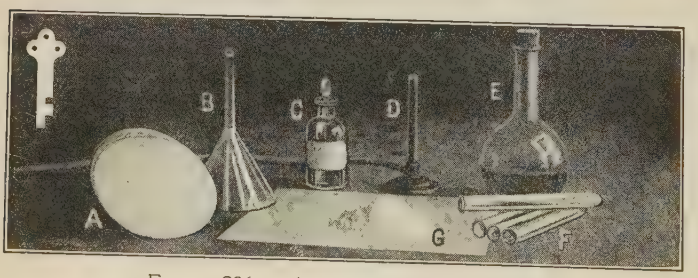


Figure 286. — (Key) Demonstration 50.

A, filter paper; **B**, funnel; **C**, iodine; **D**, Bunsen burner; **E**, Fehling's solution; **F**, test tubes; **G**, starch.

(Key) Demonstration 50 : ***Problem: How does saliva act upon starch?***

Materials: Starch; test tubes; iodine; Fehling's solution; Bunsen burner; a funnel; and filter paper (Fig. 286).

Method: A. Collect some saliva in a test tube. Filter it.

B. Boil some starch in water for 30 seconds in a second test tube, making a thin paste.

C. Test the starch with iodine. Why do you do this?

D. Test the starch with Fehling's solution. Why do this?

E. Test the saliva with Fehling's solution. Why do this?

F. Mix some saliva with the boiled starch and set aside for 10 minutes in a beaker containing water at 90° F. Shake occasionally. Why?

G. Test the contents of the test tube in (*F*) with Fehling's solution.

Observations: What effect does boiling the starch have upon it? Do you find sugar in starch? Do you find sugar in saliva? Do you find sugar in the test tube containing saliva and boiled starch? Now test the saliva with iodine. Do you find any starch here?

Conclusion: What effect does saliva have upon starch? Prove your answer. Then write out a complete account in your Science Discovery Book.

466. Digestion of Food. — Suppose that you follow a beef sandwich through the digestive tract or *alimentary canal*, noting what happens and thus becoming familiar with the most important parts of the tract. The sandwich consists of bread, lean meat, and butter. There is protein in the bread, meat, and butter, starch in the bread, fat in the lean meat and a large amount of it in the butter, while the bread contains a trace of sugar placed there by the baker.

a. The Mouth. When a bite of sandwich is taken, it is chewed and mixed with saliva. Saliva is a liquid which is present in the mouth. It is composed of water and an *enzyme* (ĕn′zīm) or *ferment* called *ptyalin* (tī′ȧ-lĭn). It acts upon the starch in the bread, changing part of it to *grape sugar*. The tongue, teeth, hard palate, lips, and cheeks all help in mixing the food with the saliva. At the proper time, this softened food, if properly chewed, passes down the gullet without any conscious act of swallowing. Try this for yourself. Most people, it must be admitted, force the food down by strenuous muscular contractions of the throat. This is wrong. Why?

b. The Stomach. Once the food is in the stomach (Fig. 287), it is churned about by the gentle motions of the stomach walls, which are composed of three layers of muscles, all working in different directions. There are glands in the walls of the stomach, which secrete a juice called the *gastric* (găs′trĭk) juice, composed of water, pepsin, and .2% of hy-

drochloric acid. Here the proteins are partially changed to a soluble form called *peptone*. The fats and starch of the sandwich are liquefied and *acid'ified*, ready to be ejected into the small intestine.

c. The Small Intestine. This part of the canal is in some ways the most important part of the whole digestive system. It is about 20 feet long and about one inch in diameter in the adult. Here the food is moved along by the slow contracting of the walls of the intestine (a process called *peristalsis*[1] (pĕr'ĭ-stăl'sĭs) and is thus thoroughly mixed again with a new digestive juice, wonderful in its triple action. The acid nature of the food as it comes from the stomach stimulates the action of the pancreas (păn'krē-ăs) and the liver, whose juices are alkaline in nature, like the saliva in the mouth. Both organs have a common outlet into the small intestine just below the stomach, where their juices, the *pancreatic juice* (păn'krē-ăt'ĭk) and the *bile* enter and mix with the food as it passes this outlet or duct (Key Picture 19).

The pancreatic juice is composed of three separate enzymes, one of which acts upon such starch as has escaped the action of the saliva; another acts upon such proteins as have escaped digestion in the stomach; while the third breaks up the fats of the butter and meat into exceedingly small particles, making an *emulsion*.[2] Further changes result in the formation of *soaps*. These substances can then be readily absorbed through the walls of the small intestine by the process of *osmosis*. The bile, without doubt, aids in emulsifying the fats. Glands in the walls of the small intestine pour intestinal juices on the food. This juice helps the pancreatic fluid and the bile to complete the digestion of all nutrients.

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[1] Peristalsis: a term applied to the muscular movements of the walls of the intestines.

[2] Here an emulsion is a quantity of liquefied fat, the particles of which are broken up and each surrounded with a film of bile in such a way that they cannot join together again, thus being easily absorbed through the walls of the small intestine.

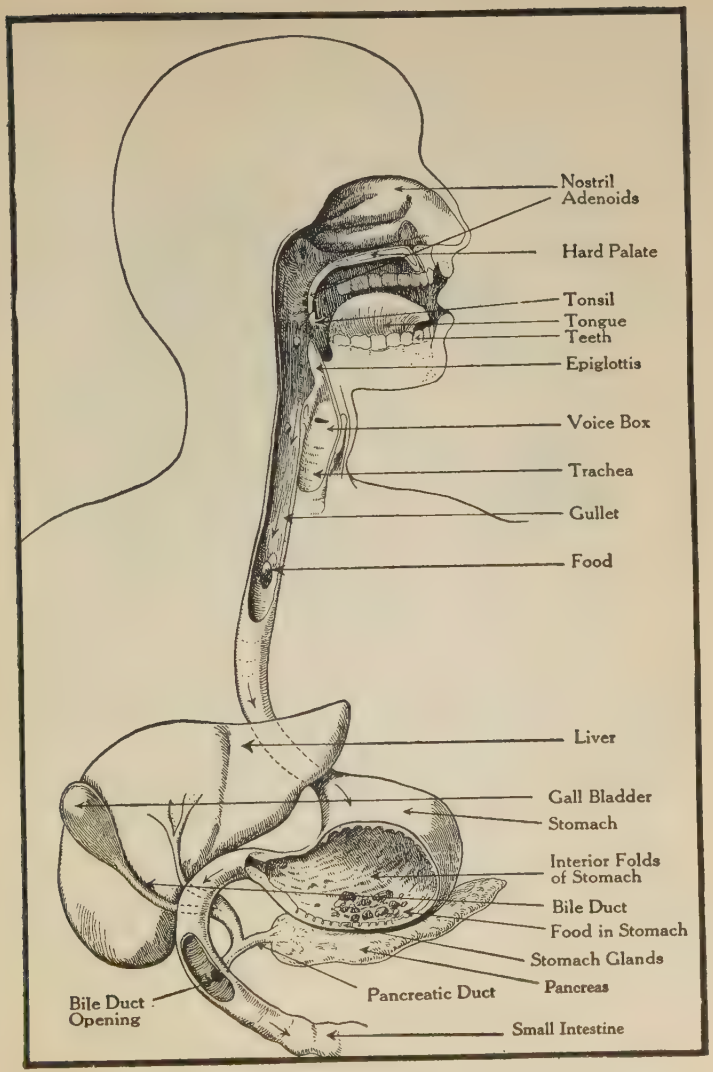

FIGURE 287. — MOUTH, GULLET, STOMACH, AND INTESTINES.

Learn every label here shown. Know the functions of each part labeled. Be sure to understand the relations of these parts to each other.

The structures peculiar to the small intestine are the *villi* (vĭl'ī), which are minute projections reaching out into the pathway of the foods and being entirely immersed by them. Study Figure 288 and explain it (Key Picture 19).

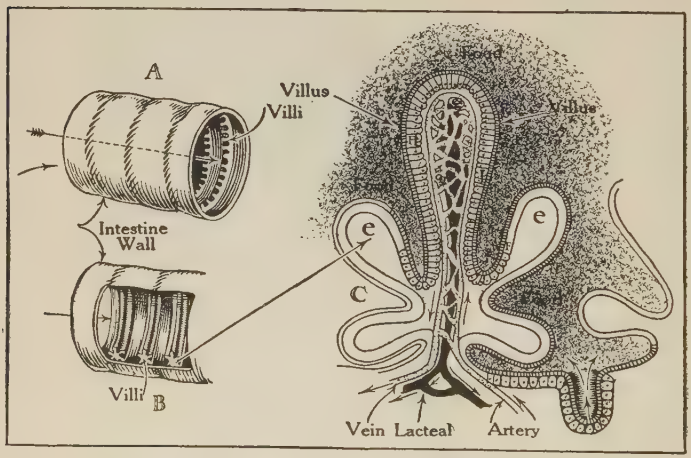

FIGURE 288. — THE VILLI, — FOOD-ABSORBING SURFACES OF THE SMALL INTESTINE.

A, a section of the small intestine showing the ridged structure and attachment of the villi. **B**, a section cut away from the side of **A** showing a cross section of the ridges with several villi attached. **C**, a single set of villi greatly enlarged. **e**, **e**, villi. **F**, cells of the wall of the villus which absorb digested food and pass it on to the blood capillaries inside the villus or across the spaces marked **G** to the lacteal tube. What nutrient alone goes to the lacteal? What nutrients go to the capillaries?

Meanwhile the refuse and whatever foods were not digested on account of poor mastication or because they were indigestible are passed into the large intestine to be stored until such time as it is convenient to eliminate them from the body.

One may ask: What has become of the beef sandwich and the sugar in the bread? The sandwich lost its identity as a sandwich in the mouth. All its parts were mixed together and all the like nutrients in its separate parts were acted upon

in the appropriate place and made soluble. The cane sugar, although it will dissolve, cannot be absorbed because its molecules are too large. It must be changed to a simple sugar by the *invertase* (ĭn-vûr′tās) of the intestinal juice.

467. Summary of Digestion. — Copy the following tables in your notebook and fill in the blanks with the proper items, using the text and the diagrams as a basis for your work.

1. Part of Canal	Food Digested	By What Digested?	Into What Changed?
a.			
b.			
c.			
d.			
e.			
f.			
g.			

2. Starch	Where Digested?	Into What Digested?	By What?	Why Changed?
Sugar				
Proteins				
Fats				

468. The Importance of Soluble Foods. — The great function of the digestive system is to (1) make insoluble foods soluble, (2) liquefy soluble foods, and (3) to absorb all liquid foods. Without careful performance of the first two the last step cannot be properly accomplished. Otherwise *malnutrition* (măl′nū-trĭsh′ŭn) and sickness result. *The proper chewing of the food is absolutely essential to the proper health and running of the human engine.*

469. Food Transportation in the Human Engine — The circulatory system carries the transformed food. It is composed of a central pumping station, the *heart*, with connecting blood vessels consisting of *arteries*, *veins*, and *capillaries* (kăp′ĭ-lă-rĭz). Study the diagram of the circulation, noting its parts, their connection, and the course of the blood

through them. Note especially the organs reached by the blood stream (Plate V).

Laboratory Exercise : *Problem: To understand the structure of the blood.* Secure a compound microscope, a glass slide, a cover glass, a Bunsen burner or alcohol lamp, and a needle.

After sterilizing the needle, by heating it in the flame, prick the skin in some soft place in the hand and cause a slight flow of blood. Mount a drop of the blood on a slide by touching the slide to the blood, cover it with a cover glass and mount under the low power of the microscope.

Note the great numbers of small straw-colored circular bodies floating in the water. They are shaped like pennies with their edges rounded and their centers slightly hollowed. Find numbers of them piled up as you would pile pennies. These objects are the *red corpuscles*. Our blood is red. Why are not these corpuscles red? It is because you see them singly here. It takes millions upon millions of them together to give a red color. It is figured that there are more than 5,000,000 of them in a drop of blood as large as a pinhead. Can you find any somewhat irregular colorless cells? They are the *white corpuscles* of which there is one to about every thousand red corpuscles. Make any other observations that you can about this blood.

Write out in your Science Discovery Book a full description of red blood corpuscles. What do you suppose their value to be to the human body?

2. How Foods Are Carried to the Cells

470. The Function of the Blood and Its Circulation. — The blood is probably the most important tissue of the whole body. It is the very life of the body and when more than one-third of it is suddenly lost, death ordinarily follows. It is composed of solids (the red and white corpuscles) and a liquid (the *plasma*), which in turn contains *serum* (sē′rŭm), *anti-bodies, blood plates, soluble foods, dissolved minerals, enzymes, internal secretions,* and *fibrinogen* (fī-brĭn′ŏ-jĕn). Try to find out the function of each of these parts. The red corpuscles carry oxygen to the cells and carbon dioxide away from the cells, while the white corpuscles destroy bacteria which may get into the blood stream or among the body cells.

William Harvey (1578–1657)

Born at Folkstone, in Kent, of a London family of great respectability, Harvey was sent to Cambridge at the age of fourteen. At nineteen he traveled in France, Germany, and Italy. In Italy he began the

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study of medicine, at Padua, under the instruction of Fabricius. Fabricius was a great anatomist and showed Harvey that the veins possess valves.

Obtaining his medical degree in 1602, Harvey returned to England to practice his profession. Meanwhile he was constantly thinking of the valves in the veins and what they might teach him. His many experiments led him to believe in the circulation of the blood. He announced his discovery in 1616. It aroused great opposition and jealousy and almost ruined his medical practice. But after twenty-five years of constant lecturing and demonstrations he lived to see his ideas completely accepted. He died in 1657, leaving to the world the discovery which became the basis of all our knowledge of disease infection, cell respiration, cell nutrition, excretion, and general life functions.

This blood stream, containing all the above-named substances and many more, must pass in close contact with every cell of the body, since it carries food, oxygen, and other needed materials to these cells and takes away from them water, carbon dioxide, and wastes containing nitrogen. You might compare the blood going out to the cells to a big delivery wagon, delivering supplies (oxygen and food) to the

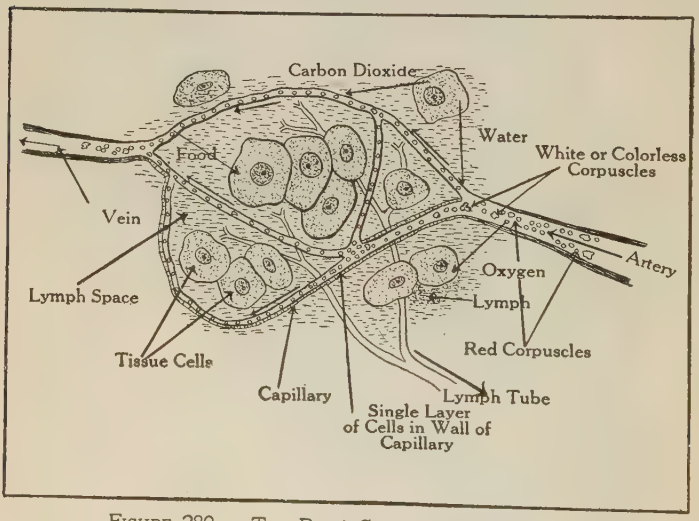

FIGURE 289. — THE BODY CELLS AND THE BLOOD.

Note direction of blood flow. What substances leave the blood? Where do they go? What are they then called? What substances go into the cells? What pass out of the cells?

consumers in the suburbs (cells) (Fig. 289). The same blood then acts as a garbage cart, taking wastes from the different parts of the body (cells) to the places where these wastes are to be eliminated from the body. The *lymph*[1] (limf) is a middleman which carries materials from blood to cells and from cells to the blood. (Study Plate V.)

[1] Lymph is plasma (minus the red corpuscles) which has escaped through the walls of the capillaries, carrying materials valuable to the cells. It also carries wastes from the cells to the capillaries.

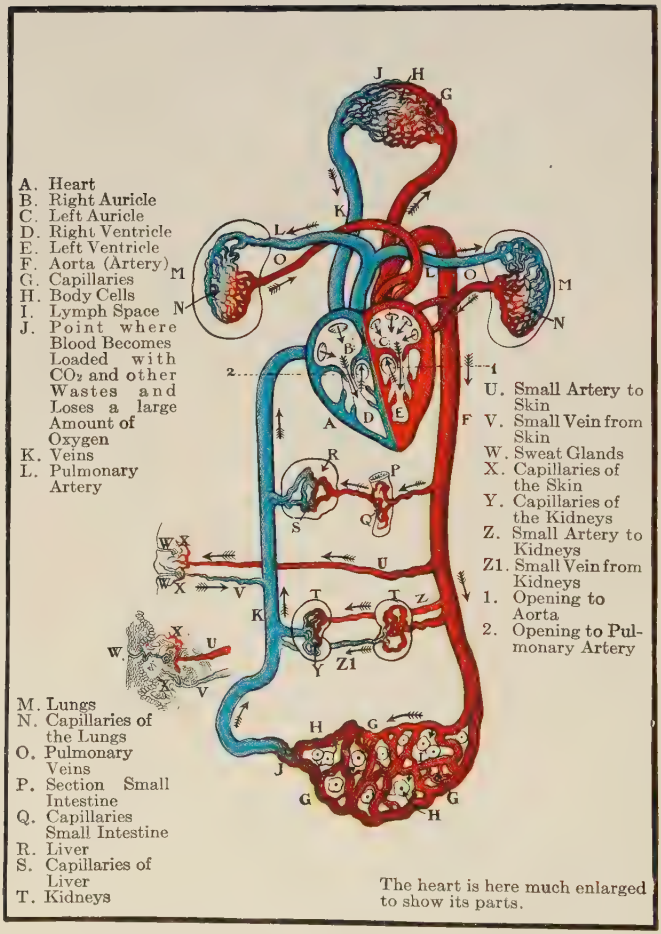
A. Heart
B. Right Auricle
C. Left Auricle
D. Right Ventricle
E. Left Ventricle
F. Aorta (Artery)
G. Capillaries
H. Body Cells
I. Lymph Space
J. Point where Blood Becomes Loaded with CO_2 and other Wastes and Loses a large Amount of Oxygen
K. Veins
L. Pulmonary Artery
M. Lungs
N. Capillaries of the Lungs
O. Pulmonary Veins
P. Section Small Intestine
Q. Capillaries Small Intestine
R. Liver
S. Capillaries of Liver
T. Kidneys
U. Small Artery to Skin
V. Small Vein from Skin
W. Sweat Glands
X. Capillaries of the Skin
Y. Capillaries of the Kidneys
Z. Small Artery to Kidneys
Z1. Small Vein from Kidneys
1. Opening to Aorta
2. Opening to Pulmonary Artery
The heart is here much enlarged to show its parts.

PLATE V.—PATH OF THE BLOOD IN THE BODY.

(1) Follow the arrows and trace the complete circuit of the blood about the body. (2) How many circuits are possible? (3) Give the function of each part named in the above picture. (4) What does the blood give up or get rid of as it passes through M, S, Y, G, and X? (5) What does the blood pick up or gain as it passes through M, Q, S, X, and G? (6) What does the blood give to and take away from H? (7) Tell the story of the adventures of a red corpuscle and a bit of plasma as they pass around through the body.

The blood, then, as it passes through the villi, takes up the digested proteins and the sugars and carries them first to the liver, where some of the sugar is stored in the form of animal starch or *glycogen* (glī′kŏ-jĕn), to be used when needed. It then passes with the proteins to the *right auricle* of the heart to be pumped through a valve into the *right ventricle* (vĕn′trĭ-k'l). A succeeding beat of the heart forces the blood through a large artery (*pulmonary*) to the lungs, where it gives up much of its carbon dioxide and some water, receiving in return a new supply of oxygen. The red corpuscles are here very important. Why? The blood now flows through the *pulmonary veins* to the *left auricle* of the heart, thence through the valve to the *left ventricle*, where it is forced into the *aorta* (ā-ôr′tȧ), the largest artery in the body, and through its branches to every cell in the body. In the capillaries which connect the ends of the arteries with the veins the exchange of substances takes place. The blood then retraces its path through veins to the right auricle of the heart again, occupying from thirty to forty-five seconds in its complete circuit around the body. (Study Plate V.)

The fats, on the other hand, are picked up by the *lacteals* (lăk′tĕ-ălz) in the villi and carried by tubes through a special system which ends in the *thoracic* (thŏ-răs′ĭk) *duct*. This duct carries all the fats to a point in the neck and empties them into the *jugular vein*, where the blood is flowing with some force. This process prevents the clogging up of the capillaries and the fats are well distributed to all the cells. Study Plate V until you understand circulation of the blood.

Laboratory Exercise : *Problem: To understand how blood circulates in a tadpole's tail.*

Secure a compound microscope, a small tadpole, jar of water, and one foot of 1-inch gauze bandaging.

Place the tadpole on a glass slide and loosely wrap the bandaging, well soaked in water, about the slide and the body of the tadpole, leaving the tail exposed. Mount the slide under low power. Focus under high power.

Do you see any objects which resemble the corpuscles observed in the human blood? Do they differ from them in any way? Are the corpuscles of man and the tadpole alike? How different? Note that these corpuscles are flowing in a liquid (the plasma). Do you note the blood vessels? Are these vessels all of the same size? Does the blood flow in the same direction in all of them? Select the largest vessel you can find. This is probably a small artery. Note the corpuscles flowing from it into a very small vessel. Do any of them have to go in single file? Why? Do you note any of them caught on a bend of the vessel and bent almost double before they get by? These vessels are capillaries. Watch the corpuscles pass into larger vessels. These are veins. In what direction with reference to the heart is the blood flowing in the artery? in the veins? in the capillaries?

Do you note a pulse? What causes this? Where is it most noticeable? Where is it least noticeable? Explain this. Why would a pulse in the capillary be dangerous? Why would it interfere with the work of the blood? Explain fully with the help of your teacher.

Explain how blood circulates in a tadpole's tail.

471. Summary of Circulation. — It is plain that the *capillaries*, the *lungs*, the *small intestine*, and the *heart* are the most important parts of the circulatory system as far as you have studied it. Keeping this in mind and studying the diagrams, tell what changes take place in the composition of the blood as it passes through the first three of these places and tell why each of these structures is important. The real exchange of substances goes on in the capillaries, lung sacs, and villi, because they are all but one cell thick. The plasma leaks out through the walls of the capillaries, carrying with it oxygen and nutrients for the cells. It is now lymph. The cells absorb the oxygen and food. However, the blood system is a closed one, having no openings, and it is only by accident that some of the blood stream finds an outlet to the outside, by a rupture or cutting of the skin, thus severing a capillary, a vein, or sometimes an artery.

472. Aids to Body Processes. — There are many internal secretions called *hormones* (hôr'mōnz), produced by ductless glands, which have the power to make certain organs of the

body perform their special functions in a proper manner. Some of these hormones are *insulin* (ĭn′sū-lĭn), secreted by the pancreas; *thyroxin* (thī-rŏk′sĭn), produced by the thyroid gland in the neck; and *adrenalin* (ăd-rē′năl-ĭn) made at the top of the kidneys. Try to find out the function of each juice.

3. Hygiene of the Blood System

473. Cuts and Bruises. — A small cut means the severing or bruising of many capillaries, and the blood simply oozes out. Cleaning the part with pure warm or cold water, touching it with iodine solution, and covering with sterilized bandaging generally means the end of the matter. A deep cut may mean the severing of a vein, which is indicated by an abundant but steady flow of blood. The cutting of an artery is recognized by the intermittent spurting of the blood. Can you explain this difference in flow? In both cases, a *tourniquet* (tōōr′nĭ-kĕt) (Fig. 290) should be made and at once applied always, *between the cut and the heart in arterial bleeding and between the cut and the body extremities in venous bleeding*. Explain. Study Figure 290 and learn how to apply the tourniquet. In portions of the body where a tourniquet cannot be applied, use thumb pressure at the proper spot. In

Figure 290. — The Tourniquet.

Note the knot and the stick. The bandage must go about the cut, the knot over the cut artery or vein, and the stick tighten the knot by twisting it. How tightly should the knot be twisted?

all cases of heavy bleeding a physician should be summoned at once. How can you stop nose bleeding?

The clotting of the blood is the thing sought in every case of bleeding. This is brought about by the formation in the blood when exposed to the air of a sticky, jelly-like mass of fibers called *fibrin*. This fibrin soon forms a *scab*, which

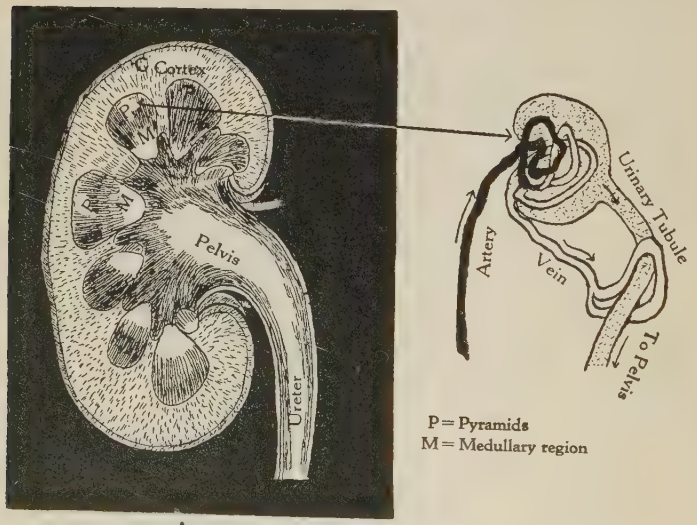

FIGURE 291. — THE STRUCTURE OF THE KIDNEYS.

A, a kidney split in half. In the pyramids urine is extracted from the blood, carried through the medullary region into the pelvis, thence into the bladder through the ureter. B, a pyramid much enlarged.

drops off when the wound is fully filled up with new tissues formed from materials which are furnished by the blood.

To open a hole in the circulatory system of the human engine is like cracking a cylinder, or bursting a gasolene tank or smashing a radiator in an automobile. It seriously interferes with all work, unless at once repaired.

474. Body Wastes. — In the human engine (1) the *lungs* function as a very important waste station where the elimina-

tion of much carbon dioxide and water occurs. (2) The *skin*, rich in capillaries, is a general waste station. Slight traces of carbon dioxide, great quantities of water and salt, and traces of nitrogenous materials are eliminated through its pores. The amount eliminated depends upon the body temperature, the surrounding air, and the kind of work the body is doing. With these surface wastes goes the excess heat of the body, and we are cooled by the evaporation of perspiration. (3) The third general waste station consists of the *kidneys*, where urea, uric acid, products of putrefaction from the intestines, and water are extracted from the blood, formed into *urine* (ū′rĭn), accumulated in the bladder, and given off from the body at intervals through the *urethra* (ū-rē′thrȧ) (Fig. 291).

475. Hygiene of the Excretory System. — To run smoothly and efficiently, an automobile engine must be kept free from carbon deposits. It is just as necessary to keep in perfect condition the human engine waste stations. You can help to keep the *lungs* free from disease germs and foreign matter by taking at least twelve deep breaths every day, in the open air, and standing as erect as possible while doing it. The *skin* can be kept toned up by bathing in warm water at least twice each week to remove the accumulated wastes upon its surface. Also cold shower baths, taken each day if possible, stimulate the action of the capillaries and increase the flow of blood through the skin. Drinking plenty of water helps the kidneys dissolve and filter out the wastes through their tubules, and by eating sparingly of proteins no strain will be placed upon the kidneys in removing urea from the blood. Plenty of exercise will help the liver and intestines remove their wastes also, and total abstinence from the use of alcoholic stimulants will prevent the breakdown of these organs.

4. Importance of the Teeth

476. The Teeth as the Foundation of Bodily Health.— Few people use their teeth to do thoroughly the thing for

which they were intended, — the chewing of food. Unless food is thoroughly mixed with the saliva all other digestive processes are poorly carried on, absorption is not complete, and the body is undernourished. This means a reduced bodily resistance to disease. Other chronic (krŏn′ĭk) disorders often follow poor digestion. It is now sufficient to say that thorough mastication of food is a habit, which everyone ought to form because it means greater health and happiness, and a longer life.

477. Structure of the Teeth. — Everyone should know something of the structure of his teeth so that he may take proper care of them. While the teeth in your jaws differ somewhat in appearance and in their special functions, yet their general structure is the same. Study the diagram of a tooth (Key Picture 19), and answer the question upon it.

478. Danger Signs. — Some people are foolish enough to crack nuts with the teeth. Others accidentally break the *enamel* (ĕn-ăm′ĕl) by biting upon hard foreign substances in the food or weaken it by too hot or too cold liquids. Again, food is allowed to lodge between the teeth which, in putrefying, gives off certain acids. These gradually destroy the enamel, producing a cavity and exposing the *dentine* (dĕn′-tĭn). The first sign of this condition is an ache. If not at once stopped by proper cleaning and filling by a competent dentist, the tooth breaks down, the crown is destroyed, and heroic measures are necessary to save what is left of the tooth. This means more pain and greater expense. Finally, the tooth is gone, a stump remains, or an enormous cavity must be filled with an artificial tooth. *In just the proportion that one neglects a decayed tooth, in just that proportion will the expense and pain increase.*

479. Care of the Teeth. — To prevent decay — for prevention is always better than cure — the following rules should be followed: (1) Be careful to avoid chewing upon any very hard substances when you eat. (2) Thoroughly clean the teeth at least once each day. (3) Visit a dentist

in whom you have the greatest confidence at least once every six months, have the teeth looked over, cleaned, and all cavities filled. Such rules if followed will result in (1) little or no toothache, (2) little discomfort while in the dentist's chair, (3) relatively low dental bills, and (4) more comfort, better digestion, lack of an offensive breath, and a great reduction in the number of cases of inflammation of the throat, stomach, and intestines.

480. Constipation and Indigestion. — *Constipation*, which is the infrequent and difficult moving of the bowels as a result of the hardening of the refuse in the large intestine, is largely traced to the improper chewing of the food, which may in turn be due to poor teeth or hasty eating.[1] Foods which reach the same intestines in lumps cannot be easily absorbed. A rapid putrefaction of the refuse and undigested foods then begins. Poisons or toxins are soon given off in the form of gases and liquids, which are absorbed into the blood and carried through the body, resulting in headaches, indigestion, offensive breath, and general inability to do work.

This is a serious condition and makes necessary the use of (1) more vegetables, fruits, and " roughage " in our daily diet, and *rarely* (2) physic or a purgative to soften the intestinal contents. Both methods will increase peristalsis. Which method is better?

Indigestion is another chronic condition of the alimentary canal due to lack of sufficient juices to digest a large quantity of food eaten. But this lack is largely due to *rapid eating of food.* The condition often results in catarrh of the whole intestinal tract and lack of power to resist disease. Such conditions can be generally remedied by forming proper habits of eating, by the selection of a proper diet, and the calling in of a competent physician.

481. Head and Stomach Aches. — Headaches are generally caused by indigestion or constipation, which in turn are

[1] Other causes of constipation will be found under *Handicaps* in Section 482.

often the result of too rapid eating. A common remedy is the headache powder, which is dangerous. Why? One should seek the cause of the headache and, if possible, remove it. A change in habits of eating, the use of a large quantity of fruits and vegetables, a purgative or plenty of exercise, and the drinking of large quantities of water will often relieve the situation. If not, the eyes or nervous disorders may be the cause; in that case an oculist or physician should be consulted.

"*Stomach*" *aches* are generally caused by the formation of gases from improperly digested foods lying in the stomach, which cause pressure and pain. A glass of hot water and bicarbonate of soda (half a teaspoonful) will often relieve this condition and neutralize the excess amount of acids in the stomach which cause what is known as a "sour stomach." If the hot water with soda or ginger does not give relief, a physician should be called.

5. Care of the Human Engine

482. Aids and Handicaps to Body Efficiency. — Any athlete worthy of the name knows that he must follow certain hard and fast rules to enable him to compete successfully with other athletes. There are *aids* and *handicaps* to his success. Training aids him. Hot weather handicaps him.

In your daily life you also have aids and handicaps which profoundly affect your general well-being and efficiency. Some of these have already been mentioned. They may well be summarized below.

Aids: 1. *Plenty of good, wholesome food.* This has already been emphasized and needs no further discussion here.

2. *Plenty of exercise.* In order to increase blood circulation, body activities, and to tone the muscles, one should walk or play at least one hour each day in the open air. Headaches and indigestion are all results of under-exercise.

3. *Sleep.* With the exercise comes the action of muscles, which are thus burned out and in turn fill up with toxins or wastes. To permit the body to remove all wastes and take them to the excretory

organs *requires rest* and plenty of it, — 8 hours of sleep for every growing boy or girl and 15 minutes extra for each year one is below 20. Sleep also allows the body to rebuild the worn-out cells.

4. *Emotional control* is essential to success. More about this may be read in Chapter XX. One who cannot use his or her will to control the emotions will be in an exhausted state a large part of

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1. Take vigorous outdoor exercise daily.

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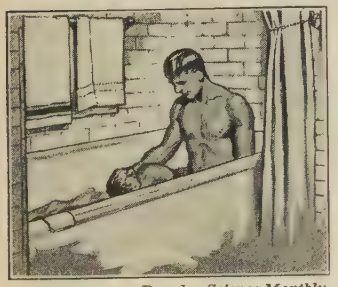
2. Avoid overeating. Don't eat too much meat or pie.



Popular Science Monthly.

3. In the morning take a cold dip, then a brisk rub.

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4. Get plenty of sleep in a well ventilated room.

FIGURE 292. — FOUR GUIDEPOSTS TO HEALTH.

the time. Be calm! Do not get excited! Keep your emotions under control!

5. *Proper cleansing of the body.* This is treated at length in a later chapter, but it may well be emphasized here. The excretory organs should be kept clean by frequent and regular emptying of the bowels and bladder. This aids in internal cleanliness. Failure to do this means headaches, constipation, and other evils already mentioned.

6. *Proper eating of food.* Slow eating is an aid to health. It means proper digestion and absorption and the full use of the food. It is also economical. Explain. Too many people dig their graves with their teeth. Explain. The slow sipping of liquids is necessary also as an aid to digestion. Washing down the food with water or other liquid is little less than a crime against the body.

FIGURE 293. — THE DISCUS THROWER.

The Greek athlete pictured as the ideal type of bodily strength and vigor. How did he accomplish this? He probably followed rules very similar to the 16 rules of health. What he did you can do. Try it.

Handicaps: 1. *Overeating* is a common handicap to efficiency. He who leaves the table in a physically and mentally logy condition is of little use to himself or to anyone else. Too much food acts as poison to the body. The cells can use a certain amount of food and no more. Over-eating is poor economy. Why?

2. *Late hours* are tremendous handicaps to efficiency. The night prowler among the young never forges ahead in his life calling. Body wastes are accumulated during both day and night to be eliminated and the result is that such persons fall an easy victim to disease because their powers of resistance to disease are brought to a very low stage.

3. *Overwork.* Few of us are guilty of this, but it is a danger nevertheless. Most accidents occur to people who are under continual strain, either mental or physical. Continuous, monotonous work is deadening, especially with long hours, and if this cannot be avoided, the work should be changed. The worker is of more importance than the job.

4. *Excitement.* Life has become so full of such wonderful interests that many people are forgetting how best to use their leisure time. Good health demands periods of repose, not merely sleep, wherein

the body and mind may be occupied with the calmer, more serious things of life. Movies, dances, parties, — all have a place in our pleasures but they must be of the right sort and taken in moderate doses. The growing boy or girl cannot afford to use up his nervous energy and muscular powers in "chasing" excitement. Can you prove this statement?

5. *Tobacco.* This has been mentioned before and will be discussed again. The "Little White Slaver" — the cigarette — is a terrible handicap upon the young of to-day. Read what Thomas Edison says of it. If you will not believe what he says, you will believe no one.

In a letter to Mr. Henry Ford he says:

> The injurious agent in cigarettes comes principally from the burning paper wrapper. — It has a violent action on the nerve centers, producing degeneration of the cells of the brain, which is quite rapid among boys. Unlike most narcotics this degeneration is permanent and uncontrollable. I employ no person who smokes cigarettes.
>
> Yours,
> Thos. A. Edison.

No further comment is necessary.

6. *Alcohol.* This is the worst handicap of all. It enslaves. It breaks down the will power. It is an economic waste. It costs the public untold millions. It is a frequent destroyer of character and success. It shortens life.

See what the Life Extension Institute says:

SAYS TESTS REVEAL ALCOHOL A LIABILITY

Director of Life Extension Institute Denies That Moderate Drinkers Live Longer

> Dr. Fisk at the Annual Conference of Social Work at Toronto said that the increased death rate among occasional users of alcohol is 19%; the increased mortality among the daily users of beer is 33%, while the increased mortality among the daily users of whiskey is 66%.
>
> — *New York Times*, June 30, 1924.

It is for you to determine what your own bodily condition and state of health shall be. By closely following the four guideposts to health (Fig. 292), by making the 16 rules of Health (p. 580) your daily routine, and by refusing to indulge in the handicaps outlined above, you can practically assure yourself (barring accidents) a long and happy life.

DO YOU LIVE BY THE 16 RULES OF HEALTH?

The 16 Rules of Health

1. Ventilate every room you occupy.
2. Wear light, loose, and porous clothes.
3. Seek out-of-door occupations and recreations.
4. Sleep out, if you can.
5. Breathe deeply.
6. Avoid overeating and overweight.
7. Avoid excess of eggs, flesh food, salt, and highly seasoned foods.
8. Eat some hard, some bulky, some raw foods.
9. Eat slowly.
10. Use sufficient water internally and externally.
11. Evacuate thoroughly, regularly, and frequently.
12. Stand, sit, and walk erect.
13. Do not allow poisons and infections to enter the body.
14. Keep the teeth, gums, and tongue clean.
15. Work, play, rest, and sleep in moderation.
16. Keep serene, — don't worry.

— *The Life Extension Institute.*

SUMMARY

The *human engine* prepares food by attacking it in the alimentary canal with several *ferments* or *digestive juices*, which make it *soluble*. The *starch* is changed to *grape sugar* by the *saliva* in the *mouth* and the *pancreatic juice* in the *small intestine;* the *proteins* are changed to *peptones* by the *gastric juice* in the *stomach* and the *pancreatic juice* in the *small intestine;* the *fats* are *emulsified* and changed into *fatty acids* and *soaps* in the small intestine by the *bile* and the pancreatic juice; while the *cane sugar* is changed to grape sugar by the *intestinal juice*. *Mineral matter* is dissolved in the *stomach* and in the *intestines*. Practically all digested foods are absorbed by the *villi* and are carried either directly or indirectly into the *blood stream*, to be sent through the *circulatory system* — consisting of *heart*, *arteries*, *veins*, and *capillaries* — and thence, with the help of the *lymph*, to the *cells*, where they, together with *oxygen*, are absorbed by the cells by *osmosis*.

The food is built up into the cells by *assimilation* and is then oxidized to release *heat* for growth and bodily functions. The *wastes*

consisting of *water*, *carbon dioxide*, *nitrogenous wastes*, etc. are withdrawn from the cells and carried by the blood to special organs of excretion, such as the *lungs*, *skin*, and *kidneys*.

The *teeth* are the foundation of bodily health. Good teeth aid in good digestion, complete absorption, and an active and healthy body. Bad teeth often cause *poor mastication*, *indigestion*, *constipation*, *poor health*, and *loss of efficiency*. For this reason the teeth should receive special care by frequent and regular cleaning, examination by competent dentists, and filling when necessary. Probably a majority of all the bodily diseases are traceable directly or indirectly to bad teeth.

The general efficiency of the body depends, then, on *good teeth*, *proper foods* and proper methods of using these foods, *proper amount of sleep*, the *drinking of much water*, *plenty of exercise* in the open air, *plenty of air while sleeping*, and the *non-use of stimulants* and *narcotics*. Ninety per cent of those who follow out the suggestions in this paragraph will have healthy bodies and a large amount of energy, and will be able to do efficient work.

Remember that :

1. The human body is an engine.
2. The human engine must have certain kinds of fuel to do its best work.
3. The human engine must release a certain amount of heat obtained from selected fuel if it is to do its best work.
4. Good teeth are a fundamental necessity for the proper running of the human engine.
5. The human engine must be aided by the observance of definite rules of hygiene in order that it may do its work well and remain in a condition of comfort and happiness.

THOUGHT QUESTIONS

1. How will drinking much ice water affect digestion of food?
2. Why is warm soup valuable at the beginning of a meal?
3. Why should one eat some raw food every day?
4. Give directions for stopping the following: Nose bleed; bleeding artery; bleeding vein. Explain each treatment.
5. Make a first aid study of the treatment of cuts and bruises. Practice on a friend the use of bandages and explain your methods to the class.
6. Tell where each nutrient in a cheese sandwich is digested, by what enzyme each nutrient is acted upon, and into what each nutrient is changed.

7. If an artery were accidentally cut, where would you place the tourniquet? Explain. Where would you place the tourniquet if a vein were cut? Explain.

8. Secure from an insurance company figures to show the effects of alcohol and tobacco on the expectancy of life and report to the class.

9. Secure statistics of the effect of tobacco and alcohol on scholarship in school and report to your class, giving reasons for the points you make. (Secure booklets from the Scientific Temperance Federation, 73 Tremont St., Boston, Mass.)

10. Why is it wrong to wash down food with a liquid of any kind?

11. A boy said: "Watch me get on the outside of this apple." He then ate the apple. Was he correct in his statement? Explain.

12. Capillary walls are but one cell thick. What is the advantage of this?

13. Could a man live without a stomach? Explain.

14. "Old age and dyspepsia go hand in hand." Explain.

15. "An army marches on its stomach." Explain.

16. Every cell in the body needs oxygen and food and must get rid of its wastes. How is this accomplished in the case of a muscle cell in your big toe?

17. Why is it wrong to begin eating when the body is overtired or the mind is in a state of excitement?

18. Why will bacteria and other parasites grow better in the small and large intestine than in any other part of the digestive system?

SPECIAL PROBLEMS

1. Make a study of the alimentary tract in your body.

a. Carefully study the parts of the alimentary canal in a mounted dissected toad or frog. Copy and label all the parts in your Science Discovery Book.

b. Study the alimentary tract or canal in a human manikin or chart. Copy and label all parts. Compare with frog tract and connect similar parts with common labels.

c. Draw lightly with chalk the path and parts of the alimentary canal upon the coat of one of your class members who has a black suit of clothes. Note the corrections by the teacher. Make a rough sketch of the human trunk upon the blackboard and put in the alimentary tract, labeling all parts and giving their functions. Copy the best drawing upon the board into your Science Discovery Book for reference.

2. Study the structure and parts of a human tooth.

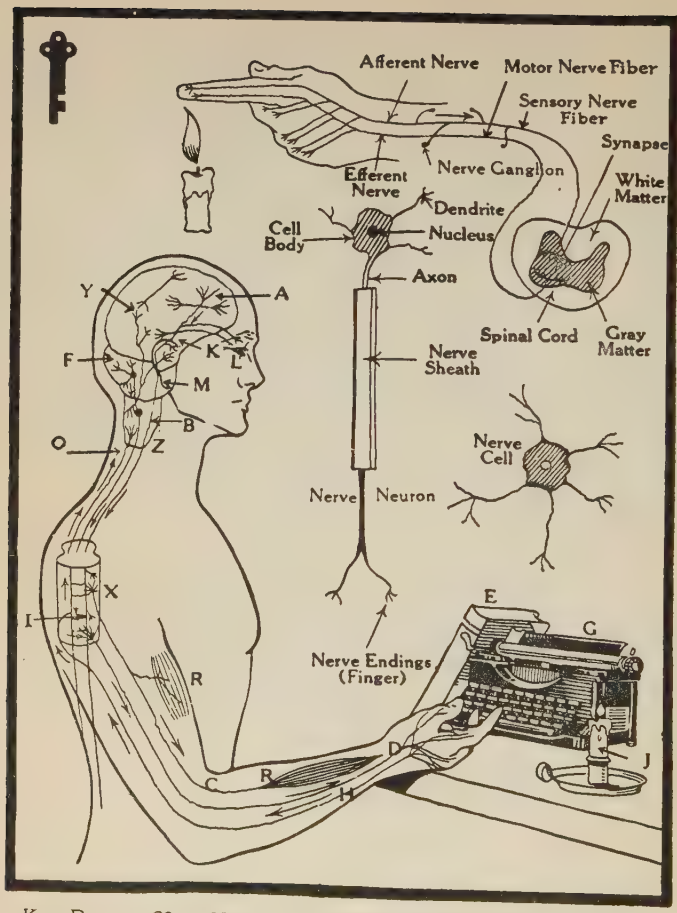
a. Note the teeth of a dog, cat, horse, cow, rabbit, guinea pig, or other animal. Does it have more than one kind? Do the teeth of one kind of animal differ from those of another? Observe the food each kind of animal eats and see if you can find a reason for the difference in dentition (arrangement of the teeth).

b. Study your own dentition either by observing a human skull or your own mouth with the use of a small mirror. Note the number of kinds of teeth you find, the total number of teeth, and the total number of each kind. Now see if you can find in your own mouth representatives of every kind of tooth found in the dog, rabbit, and horse. Does this give you any light on the kinds of food the human engine needs? Explain.

c. Examine the longitudinal section of a human tooth, preferably a " canine " tooth. Sketch it. Label the enamel, crown, dentine, root, cement, and pulp cavity. Try to work out the use of each part. Can you suggest anything based upon your study of this tooth that should be done to care for a tooth?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Ferguson. A Child's Book of the Teeth. World Book Co.
Hutchinson. Building Strong Bodies. Houghton Mifflin Co.
Fish and Fisher. How To Live. Funk and Wagnalls Co.
McFee. Food and Health. T. Y. Crowell Co.
Rossiter. Romance of a Living Temple. Sully.
Walters. Principles of Health Control. D. C. Heath & Co.
Winslow. Healthy Living. American Book Company.



KEY PICTURE 20. — HOW YOUR CENTRAL NERVOUS SYSTEM WORKS.

The man sees the book **E** by means of the nerves at **L**. At **A** his will tells him to pick up the book. An impulse travels from the *cerebrum*, **Y**, along the motor nerve **B** to the nerves and muscles **RD**. The muscles contract and the book is lifted. This is a *voluntary act*. If the man learns to use the typewriter, he repeats certain voluntary acts until they become *automatic*. If the man burns his finger in the flame of the candle **J**, his sensory nerves carry a message to the spinal cord. Then the nerves at **X** cause him to withdraw his finger without the command of his will. This is a *reflex act*. **F** denotes the cerebellum; **MZ**, the medulla oblongata; **IX**, a section of the spinal cord; and **C**, **H**, and **O**, nerve courses.

CHAPTER XX

THE WORK OF CONTROLLING THE BODY

Then mark the cloven sphere that holds
All thought in its mysterious folds;
That feels sensation's faintest thrill,
And flashes forth the sovereign will;
Think on the stormy world that dwells
Locked in its dim and clustering cells!
The lightning gleams of power it sheds
Along its hollow glassy threads!

— Holmes.

In all your work stop and think. Constantly ask the question: What does this fact mean? You may or may not be able to answer the question, but that is no reason for dodging it.

— V. N. Spalding.

What do you know about nerves? Have you any nerves? Have you any nerve? How can you will to do anything? Would you like to know what actually controls the body and makes it work? Did you ever form a bad habit? Was it easy to break? What do you suppose your nerves have to do with habits? Do you suppose that you can destroy the power of your nervous system to do good work? How do you suppose that the body can be trained to act correctly in an emergency? All these points will be discussed in this chapter.

Some Practical Questions :

1. What is meant by the statement : " Practice makes perfect "? Explain.
2. What is meant by " a skilled mechanic "? Explain.

3. Why may trained and educated young men receive greater salaries than unskilled laborers?

4. Why do the railroads of this country refuse without a moment's hesitation to employ any man who they know drinks alcoholic stimulants?

5. What makes a person jump when someone shouts suddenly near him?

Home Problem. — Take a penny, place it on a table, reach out and touch it several times with the first finger. Then shut the eyes and touch it. Repeat this process until you can touch it every time with the eyes shut. What has happened in your brain? Explain.

Field Problem. — Study the actions of the members of your class. Determine what actions are most common to them all. Explain these actions. Observe some action which the teacher is trying to make into a habit in the whole class. What is its advantage? What is the advantage of this action to you? to the teacher?

1. The Nervous System

483. Why You Do Things. — If your teacher asks you to stand and recite, you do so. Why and how do you do this thing? You see some candy in a store window, hesitate as to whether or not you will spend your money for some of this candy, decide not to do so, and pass on your way. Why and how do you make this decision? You accidentally touch a hot steam pipe, instantly withdraw your hand, and exclaim "Ouch!" How and why do you do these things? You learn to tie a certain kind of knot. You can now tie this same knot with your eyes shut and talk to someone at the same time. How and why can you do this thing? Have you ever thought much about your actions? (Study Key Picture 20.)

484. Parts of the Nervous System and their Functions. — When you think about something at the same time that you have a pain in your side, two distinct parts of your nervous system are working. The first part is called your *central nervous system.* It consists of the *brain* and *spinal cord,*

and for that reason is sometimes called the *cerebro-spinal* (sĕr′ē-brō-spī′năl) *system.* The second part, which informs you of your bodily feelings, is called the *sympathetic nervous*

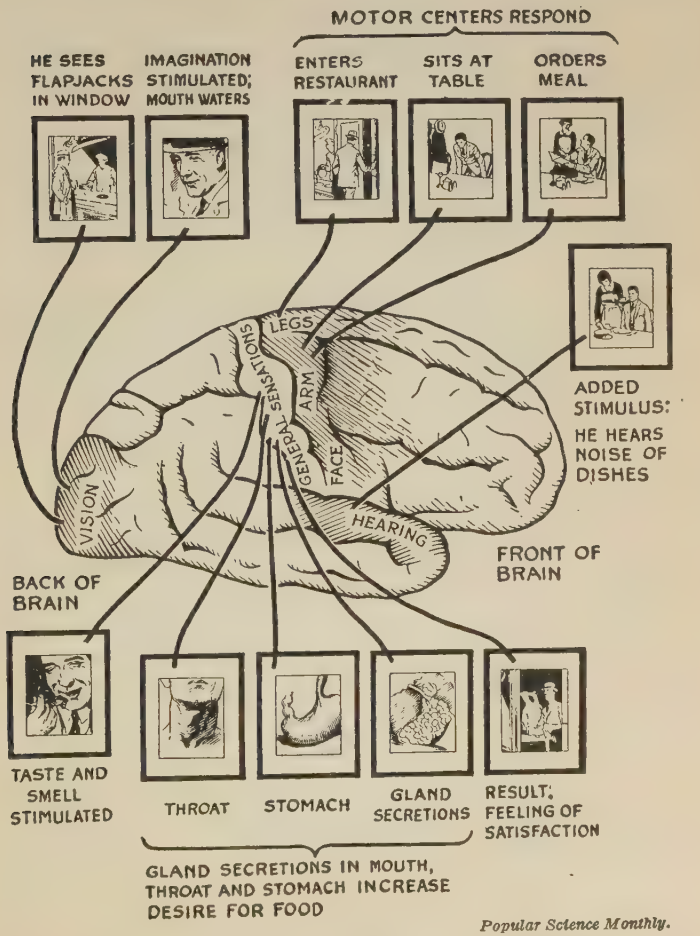


FIGURE 294. — HOW THE BRAIN CONTROLS THE BODY.

Tell the complete story here pictured in your Science Discovery Book. Learn from it the relation of your nervous system to your everyday actions.

system. When you see and feel, your *nerves* are bringing messages to your brain, where you interpret them. Nerves also run from your brain to your muscles. Messages are also sent to the spinal cord, which takes messages instantly to the right muscles, and the finger or other part of the body is moved. With this information study carefully the diagram of the nervous system and be able to understand the relations of the parts. (Study Key Picture 20.)

485. Parts of the Brain and Their Functions. — The work of the world is done by the brain of man, a mass of nerves situated in the head and connected with all parts of the body. A careful study of Figure 295 will show you several essential parts.

The *cerebrum* receives and interprets the impressions you receive through your five senses. It also is your thinking center, and all voluntary actions begin here. It is believed that as we grow older the *cerebellum* (sĕr′ē-bĕl′ŭm) relieves the cerebrum of much of its labor by *forming habits.* It is the *balancing center.* It also causes the muscles all over the body to work together and therefore *coördinates our movements.* To think quickly and to move quickly in emergencies or in doing a special task requiring skill means a full development of the cerebellum. The *medulla oblongata* (mē-dŭl′ȧ ŏb′lŏŋ-gā′tȧ) is located just below the cerebellum and seems to be a simple enlargement of the spinal cord (Fig. 295). Over this part of the brain we have no control except in a general and indirect way. Our breathing and heart actions are automatically controlled by this part. The contracting and expanding of the blood vessels are regulated here. Swallowing, vomiting, secretion of various juices, and similar acts are all controlled by this center. It, moreover, carries sensations or messages to and from the brain. If this part is injured, death results. A person may live without thinking or without proper coördination of the muscles, but he cannot live without breathing. Injury to the medulla oblongata is fatal (Key Picture 20).

486. Nerve Cells and Nerve Fibers. — Nerve cells are like other cells of the body in that they are composed of protoplasm, differentiated into *cytoplasm* (that part of the protoplasm which lies outside the nucleus) and nucleus. They differ from all other cells in that they are very large

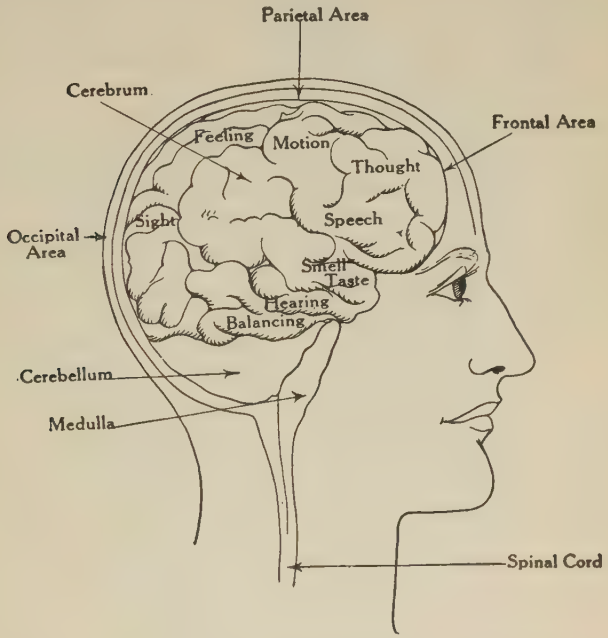


FIGURE 295. — HOW THE BRAIN IS DIVIDED INTO PARTS.
Compare this with Figure 294. Why will injury to certain parts of the head affect certain parts of the body?

and have many branches, of which one is generally much longer than the others. Observe in Key Picture 20 how irregular these cells are.

487. Afferent and Efferent Nerves. — Some nerves seem to run from the organs of the body to the spinal cord and the brain, while others run from the brain and spinal cord to the organs of the body. The first kind of nerves is

called *afferent* (ăf′ĕr-ĕnt) *nerves*, meaning "carrying to," while these which carry messages from the brain out to the muscles are called *efferent* (ĕf′ĕr-ĕnt) *nerves*, "carrying out." The afferent nerves are always *sensory nerves* because they carry sensations or stimuli from the outside in, while the efferent nerves are *motor nerves* because they move the muscles. A third kind of nerve which we do not know much about is the *association fibers* which connect nerve cells with one another in the brain.

488. Reflex Action. — If one asks you to look at a picture, you use your will power center, located in the cerebrum, and turn your eyes to the picture. You may take the picture in your hand. In doing these things you are using your brain and your efferent nerves. Your act is a *voluntary act*. It is slow and deliberate. But, if a hot steam pipe suddenly comes in contact with your hand, a message is sent along an afferent nerve towards the brain, though it never reaches that center. When this impulse reaches the spinal cord, it enters the *posterior root*[1] (see Key Picture 20) and is automatically connected with the right efferent or motor nerve which carries an impulse through the *anterior root*[2] out to the proper muscles, causing them to contract and withdraw the hand from the hot pipe. This is a *reflex action*. Common instances of reflex action are the movement of the lower limb when the knee is struck a blow with the legs crossed, and the exclaiming "Ouch" when pricked by a pin.

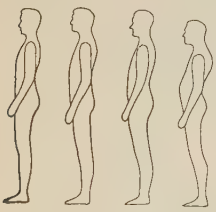


FIGURE 296. — GOOD AND BAD POSTURE.

Composite outlines of 700 Harvard College freshmen. Which are good? Which are bad? How can a good posture be secured? (Fig. 297)

[1] That part of the gray matter of the spinal cord facing the back of the body and receiving messages from the body surface.

[2] A prong of gray matter facing the front of the body, which sends out messages to the body organs.

2. The Nature and Importance of Habits

489. Habit Formation. — Another set of acts which are of great value in protecting the body and in making you successfully fit into your environment is the formation of right habits. Habits are sometimes called *automatic acts* or *acquired reflexes*. It took a long time for you to learn to eat with a knife and fork, to tie up your shoes, to walk, to talk, and to write. Now these actions are "second nature" for you.

If you have formed a bad habit the only way to break it is to form a good one in its place. Thus one can train himself to begin school work at a certain hour, to eat slowly, to wake up at a certain hour, to be courteous, to be fine mannered. To form good habits, then, you should:

1. Always act in the right way. This wears the path.
2. Use all your will power to make yourself do what you ought to do.
3. Never allow yourself to omit doing the repeated act.
4. Keep at the task until the act becomes automatic.

In this way you can form your character. Character is a bundle of habits. (What do we mean, then, when we say that a man or a woman, a boy or girl has a fine character?)

Acts repeated make habits.
Habits followed make character.
Character lived makes a destiny.

490. The Value of Forming Right Habits. — The value of your nervous system in making you an efficient individual depends upon how you use it, what you do with it, how you take care of it. After the age of fifteen most boys and girls begin to be able to do hard tasks well with their brains. It is then that good and bad habits become very important. The habits of an upright, graceful walk; of speaking distinctly; eating slowly; of keeping the hands and nails clean are all hard to form, but once formed, they last through life.

The advantages of forming right habits are many. (1) Habits save the brain time and energy, freeing it to

learn new things. (2) Habits give one time to do things in a deliberate and fine way. (3) Habits save one much time. How? (4) Habits make one skilled in any line of work he may choose to follow. (5) Habits make one of greater value in the work of the world. Experts in any line of work are trained to do their work in an efficient manner through the formation of right habits.

FIGURE 297. — THE VALUE OF HABIT FORMATION.

Two recruits "before and after" taking five months of military training. The camera tells the story. Name some factors that produced this result.

3. HANDICAPS TO THE NERVOUS SYSTEM

491. Alcohol and the Nervous System. — Nerve cells are composed of protoplasm. Protoplasm contains protein materials. What is the effect of alcohol on both these materials?

Demonstration 51 : *Problem: How does alcohol act upon protoplasm and proteins out of which protoplasm is made?*

Materials: A culture of protozoans (paramecia); a compound microscope; slide and cover glass; a test tube; alcohol; egg white.

Method: *A.* Place a few drops of the protozoan culture on the slide and cover with cover glass. Focus under the low power and observe. Note the rapidity of action of these animals. Note the protoplasm of the cell. Now place under the cover glass a drop of alcohol. Observe effect of the alcohol upon the movements of the animals and upon the protoplasm itself.

B. Place a little of the egg white in the test tube and pour into the tube about a spoonful of alcohol. Shake the tube and note effect upon the protein.

Observations: Was the action of the protozoans quickened or retarded? What caused this? Was the protoplasm affected in any way? Explain. What happened to the egg white?

Conclusion: Give three effects of alcohol upon living tissues. This demonstration is important. Keep its record in your Science Discovery Book.

If alcohol acts upon protoplasm in the way you have observed, what do you think might be its effect upon nerve cells which are made of protoplasm? Alcohol practically destroys nerve tissue, if applied to it long enough, just as it destroyed the protozoans.

The first effect of alcohol upon the nervous system is one of stimulation. The mind becomes temporarily active, due to the dilation of the brain blood vessels. But such effect is only temporary. Alcohol tends to destroy the nervous and muscular vitality of the body. Continued use partially paralyzes the nerve centers and the cerebellum, with a consequent loss of will power and self-control.

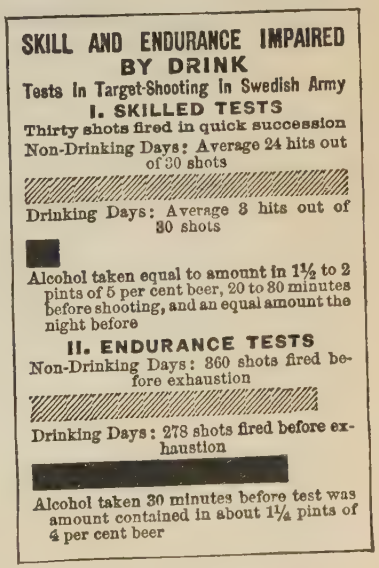

SKILL AND ENDURANCE IMPAIRED BY DRINK
Tests In Target-Shooting In Swedish Army
I. SKILLED TESTS
Thirty shots fired in quick succession
Non-Drinking Days: Average 24 hits out of 30 shots
Drinking Days: Average 3 hits out of 30 shots
Alcohol taken equal to amount in 1½ to 2 pints of 5 per cent beer, 20 to 30 minutes before shooting, and an equal amount the night before
II. ENDURANCE TESTS
Non-Drinking Days: 360 shots fired before exhaustion
Drinking Days: 278 shots fired before exhaustion
Alcohol taken 30 minutes before test was amount contained in about 1¼ pints of 4 per cent beer

FIGURE 298A. — ALCOHOL AND SKILL.
This diagram tells its own story. Explain it.

492. The Effect of Alcohol upon the Ability to Work. — The effect of alcohol upon muscular activity has been shown to be depressing by many experiments.

In the English army, it was found that when a ration of rum was served the men, they at first marched more briskly than the men not so rationed, but after about three miles of marching, the stimulus of the alcohol had worked off and these men lagged behind the others.

A second ration of rum caused them to lag behind sooner than before, but when these same men were rationed with beef tea they were stimulated and they could withstand many miles of marching without great fatigue (Fig. 298a).

Most athletic trainers will not tolerate the use of alcohol by athletes. To do so means loss of membership on any team worthy of the name. The National League managers are so strict on this

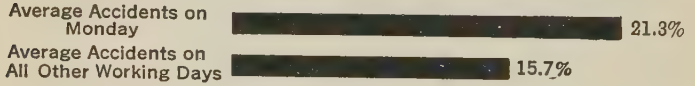


FIGURE 298B. — ALCOHOL AND ACCIDENTS.

Explain what this graph tells.

point of total abstinence by the players that they will not keep any man on the pay roll who is known to drink during the playing season. Too much money is at stake to take chances on the poor playing of a man made inefficient by liquor.

493. The Economic Effect of the Use of Alcohol. — Nowadays it is exceedingly difficult for the drinking man to secure a steady job. It costs too much to take risks on him. If such a man gets a job, he holds it but a short time because of his inefficiency.

56% of all mine owners will not employ a man who drinks alcohol; 72% of the farmers will not hire an alcohol user; 79% of manufacturers will not give a drinker a job; 89% of the trades will not take a chance on an alcohol user; while 98% of the transportation lines will not keep a man on their pay rolls who is known to drink.

One engineer who ran past a stop signal on the Delaware and Lackawanna Railroad because he had been drinking caused the loss of 40 lives, the injury of 75 more persons, and a cost to the railroad in damages of many thousands of dollars (Fig. 298b).

Careful estimates show that from one-fourth to one-half of the insane in the asylums of the state of New York were made so by alcohol. Their cost to the state each year is about $2,500,000. The sober man thinks first and acts last. The drunken man acts first and then has plenty of time afterwards, in prison, to think about his act. About 80% of the men who occupy cells in the Tombs prison in New York admitted that the use of alcohol put them there.

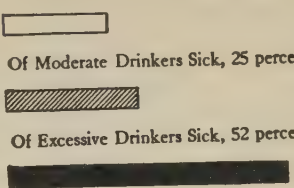


FIGURE 298c. — ALCOHOL AND DISEASE. Deaths from pneumonia. Explain the story here told.

494. Summary on the Use of Alcohol. — 1. Alcohol reduces physical strength, endurance, and work accomplished.

2. It leads to insanity.

3. It increases accidents, assaults, and crime.

4. It reduces the mental powers of persons using it.

5. It destroys efficiency in every line of work.

6. It causes a high death rate among the children of drinkers.

7. It accounts for one-third of the pauperism, one-fifth of the divorces, and one-half of the crime in the United States.

495. Tobacco and the Nervous System. — When smoked, tobacco causes a relaxed feeling because it decreases for the time being the activity of the brain cells. It does this through its poisonous effects upon the cells. No one knows just how much he really pays for a pipe full of tobacco because the actual money cost of the tobacco is the least part of it. We are assured, however, that the cost is tremendous, for the active element of tobacco, *nicotine*, is a deadly poison. How deadly can be learned by a simple demonstration.

Demonstration 52 : *Problem: To determine the effect of tobacco smoke upon a fish.*

Materials: Tobacco pipes; tobacco; a small goldfish in a jar of water; a glass tumbler; and a small piece of cheesecloth.

Method: Fill the tumbler two-thirds full of water and place the

fish in this water. Fill the bowl of the pipe with tobacco and light it. When it is well lighted, cover the bowl of the pipe with the cheesecloth and, holding the stem end of the pipe in the tumbler of water, blow the smoke through the stem by placing the lips over the cheesecloth and the bowl of the pipe. After each blowing of smoke into the glass, stop and observe the results.

Observations: When does the fish begin to act in a peculiar manner? How does the fish act? How do these actions change as you repeat the blowing of the tobacco into the water? What is the final result of the blowing? What caused this result?

Conclusion: What is the effect of tobacco (nicotine) upon the fish?

Practical Applications: A piece of nicotine as large as a pea seed if fed to a dog will kill him in a few hours. When used by the young who are growing, it is strong enough to check bone and muscle growth and it weakens the heart to such an extent that the tobacco user is "short-winded," and unsteady in his muscular movements. Athletic trainers put a ban on tobacco the moment an athlete joins a team. To allow smoking in an athletic team means loss of victories and disaster to that team.

496. Effect of Tobacco upon Mental Powers. — Experiments and observations show that tobacco interferes with scholarship.

Dr. Andrew D. White, formerly President of Cornell University, said: "I never knew a student to smoke cigarettes who did not disappoint expectations or who did not 'peter out.'" A test made with 201 boys of the schools of Illinois showed that 45 of the 124 boys who were smokers left school because they could not keep up in their work; 55 of the smokers remained in school and had an average of 70% in their work; 24 of the smokers quit smoking and had an average of 80%, while 77 non-smokers had an average of 84%.

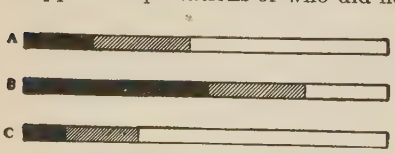


FIGURE 299. — SMOKING AND SCHOLARSHIPS.

Students in Clark College. Black areas represent habitual smokers; the shaded areas occasional smokers; the white areas the non-smokers.

A, number of students; B, number failing in studies; C, number winning honors. Explain the story here told.

In Clark College it was found that one-fifth of the students were habitual smokers. These smokers furnished more than half of the failures in the college, while the non-smokers furnished less than one-fourth of the failures.

One-tenth of the honors were won by the smokers, while over two-thirds of the honors were won by the non-smokers (Fig. 299).

In Yale College 95% of the highest ranking students are non-smokers, while the smokers furnished 60% of the students with ordinary or poor rank.

497. Tobacco and Character. — Any influence that tends to make the nerves weak and uncertain in their control over the muscles is dangerous to the will. It is a noticeable fact that young smokers are often nervous and irritable. They easily become angered. They easily lose control of themselves. Their will power is weakened and they become less and less reliable in business. The youth (boy or girl) who looks forward to excellence in athletics, to achievement in business, in the professions, to authority and control in store or factory or home, will select his or her habits, as well as his or her friends, with care and will leave tobacco out of those things which are chosen.

4. How Habit Formation Conserves Life

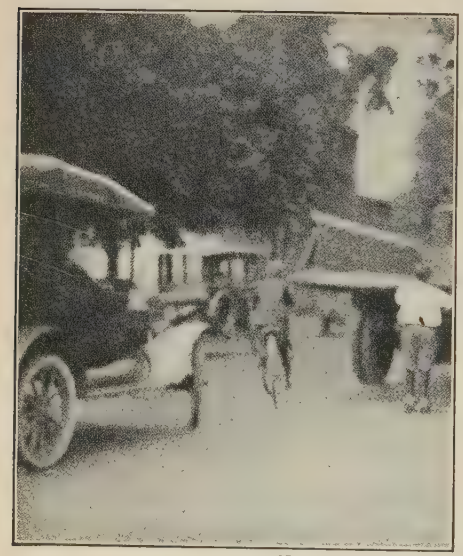
"Safety First"

498. Safety and the Nervous System. — In this day of business rush and congested traffic in our streets everybody is obliged to "watch his step." A person who buys an automobile must train his nervous system to think quickly under any and every circumstance.

What is true of the driver is also true of the pedestrian in the street. He who has not formed the habit of looking both ways before crossing the street will not live long. At block intersections he must look four ways before crossing. This is essential to-day for safety. *Safety, then, is a matter of training the nervous system.*

499. How to Avoid Street Accidents. — It is well to think just what you would do if you were face to face with a situation involving your safety. Then, if the situation arises, you are ready to do the thing you ought to do. Afterwards,

think over what you did and how you did it. What part of your brain would do this? Such thinking trains the nervous system to act automatically so that when the need arises, you do what ought to be done without losing time in deciding what to do. What part of your brain would act here?



National Safety Council.

FIGURE 300A.—A DANGEROUS GAME.

Keep away from dangers like this. One false step may snuff out your life when you run such risks.

Some of the habits you should form are as follows:

1. Cross the streets only at regular crossings. Do not "jay walk."

2. Look both ways before crossing.

3. Cross only when there is a large gap between cars or when the traffic is stopped for your crossing.

4. Look to your left in crossing the first half of the street and to the right during the second half.

5. Train yourself to go forward without dodging back if a car is coming towards you with such speed that it appears that you can not cross after having started. The driver will slow up and pass behind you.

6. In getting off street cars never cross the street behind the car until you have looked from behind it to see if a street car or other vehicle is coming from the other direction. The same rule applies in alighting from automobiles or coming from behind any obstacle in the street.

7. Never try to "hitch on" to any moving vehicle. If the vehicle is moving swiftly, you may be thrown to the ground with dangerous force and run over by another vehicle, or you may be hurled under the wheels.

8. Never run into the street in any games or after a ball until you have looked both ways to see that the road is free from cars in your vicinity.

9. Never coast into the street on sleds, skates, or bicycles.

500. Railroads and Street Cars. — Thousands of people who are not passengers are killed by our railroads every year. They walk the tracks and are run down or fall under the wheels in climbing on to trains. The worst accidents are those at grade crossings.

In the case of street cars most accidents are caused by wrongly alighting from the cars. This is done especially by women. The writer has made a special observation upon this point and fully 90% of the women he has observed alighting from cars use the *right* hand in steadying themselves and alight with the face towards the rear of the car (Figs. 301a and 301b). *Always use the left hand on the bar, face forward, and place the right foot first on the ground.*

National Safety Council.

FIGURE 300B. — TOO MUCH RISK.

A good way to die young. Both boys are taking big chances. Explain. Better be safe than sorry!

Jumping moving cars is another cause of accident. Finally, care should always be taken in stepping from behind a car. Explain.

501. Fire. — The fire losses in the United States in a recent year were nearly $500,000,000. In New York City alone, $19,000,000 worth of property was destroyed, 164 people were killed, and 207 injured in over 26,000 fires. A large

Ewing Galloway.

FIGURE 301A. — THE WRONG WAY TO LEAVE A CAR.

Why? Explain.

Ewing Galloway.

FIGURE 301B. — THE RIGHT WAY TO LEAVE A CAR.

Why? Explain.

Note: Both photographs are of cars whose exits are at the forward end.

percentage of this loss was due to pure carelessness or to a lack of a training of the nervous system in habit formation. To prevent fires respect the following simple rules:

1. Always keep the matches in a metal box and out of the reach of small brothers and sisters.
2. Never throw away a lighted match. Extinguish it before it leaves your hands.
3. Keep all kerosene or other inflammable liquids in an airtight metal can away from fire.
4. Never try to hurry up a slow fire by pouring oil upon it.
5. Always place ashes in a good metal ash can.
6. Keep your house, especially the cellar, free from rubbish.

Prepare for fire by learning and applying the following rules:

1. Have your home supplied with a pail of water or a fire extinguisher on each floor. Know how to use the extinguisher.
2. Find out the nearest fire alarm box and think just how you would get to it in case of fire. Then, if the emergency rises, you will not have to stop to think where the alarm box is.

3. Think just how you would get out of each room in your house in case of fire. If the fire comes, you will then know what to do.

4. Practice first aid in suffocation so that in case of fire you will know how to revive anyone overcome with smoke.

5. If the clothing of any person is afire or your own is afire, wrap a shawl or blanket about the body to cut off the air. Then slap or roll the body and pour on water.

6. If one is burned deeply, apply limewater and linseed oil, mixed in equal parts, or sprinkle the burn liberally with a paste of baking soda and water. Then wrap loosely with aseptic gauze. *Never use cotton to wrap a burn.*

502. Water. — Many persons are drowned every year because they "lose their heads" and do not know what to do or how to help others in the water. The following rules insure greater safety near, in, or on the water.

1. Learn to swim and dive.
2. Never try to swim long distances across streams or lakes.
3. Never stay in the water until you shiver with the cold.
4. Never go in the water soon after eating a heavy meal or when tired.
5. Never try to dive in shallow water.
6. Never go far from land unless a boat is near you.
7. Never stand up in or walk in a boat, or rock it.
8. When traveling on large boats, always find out where the life preservers are located, know how to put them on, and how to get to the decks from your stateroom.
9. In skating, never dare anyone else or accept a dare to skate across thin ice. A break through may mean sliding under the ice with fatal results.
10. To rescue a person in the water in the winter time throw him the end of a rope or pass him a board. Keep away from the edge of the ice.
11. When rescuing a person in the summer time, grasp him from behind, hold him at arm's length, and do not let him clutch your body.
12. In resuscitating a person use the Schaefer method as outlined in Chapter V. Send for a physician.

503. Bleeding. — In the case of cut veins and arteries the following rules should be observed, but drill on them in a First Aid Club is the surest way of training the nervous system to act correctly in such emergencies.

1. First determine whether a vein or an artery has been cut. How is this done?

2. If a vein, place a tourniquet around the part cut, between the cut and the end of the member affected. Do not draw it too tight.

3. If an artery is cut apply the tourniquet between the cut and the heart. Draw it tight and keep it so until a physician arrives.

4. Always place a flat stone or thin block of wood between the tourniquet knot and the body to prevent the bruising of the skin and other blood vessels. Tighten with a stick through the knot (Fig. 290).

5. Administer stimulants in the form of hot coffee or spirits of ammonia (one teaspoonful in a glass of water), if the patient shows signs of collapsing.

6. Where a tourniquet cannot be applied, use thumb pressure to check the flow.

504. Poisons. — Under no circumstances should one ever take medicine in the dark. All bottles of poison should be labeled "POISON" (Fig. 302). It is well to have an antidote written on the label. If one should take poison accidentally, quick but cool-headed action is necessary. To do the right thing is a matter of habit formation or training. It would be well for you to practice in your First Aid Club just what you would do under such conditions. Fun as well as profit can be gotten out of such practice by having various members feign sickness, each from a different poison. Then the club should be quick to suggest the proper antidote. Study and training alone will tell you what ought to be done and how to do it. Learn the following rules:

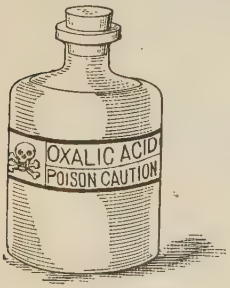


FIGURE 302. — A POISON BOTTLE.

All such bottles should be plainly labeled and tightly corked. Why?

1. Empty the stomach at once by vomiting. To induce vomiting drink a cup of warm water with a spoonful of mustard mixed in it. Then tickle the throat with the finger as far down as possible to cause gagging and vomiting.

2. If carbolic acid or lye has been taken, drink sweet oil or Russian white oil to the amount of a small cupful.

3. For bichloride of mercury, swallow the whites of several eggs.

4. For iodine, give boiled or baked potato or boiled starch.

5. Apply a hot water bottle to the stomach and wrap patient in a blanket.

6. Send for a physician.

505. Fractures and Sprains. — In all first aid work for broken bones the patient should be kept quiet and in a reclining position, if possible. A physician should be sent for at once. The following rules should be followed:

1. Bind two sticks along a broken arm to keep it from moving at the break (Fig. 303).

2. Hang the bound arm in a sling.

3. Use pillows or coats for pads, if necessary to relieve pain.

4. In case of a broken collar bone put the arm in a sling.

5. In case of a broken ankle keep the patient lying down and off his feet.

6. In case of a compound fracture (where the bone protrudes) keep all objects away from it so that no infection can take place.

7. In sprains keep pressure off the injured member. Immerse the member in hot water; paint with iodine, and when dry, apply arnica. Then bind with adhesive tape, cover with bandaging, and keep the part sufficiently active to prevent its getting stiff.

FIGURE 303. — HOW TO TREAT A FRACTURE.

Splints made of small boards should be applied to broken part and bound up with cloth or bandaging. Why? The arm should be slung from the shoulder. Why?

506. Fainting and Epilepsy. — Never dash water in the face of one who has fainted. Follow the suggestions here given, noting that the first four apply only to fainting:

1. Loosen the clothing if it is tight.
2. Lay the person down flat *with head lower than feet.*
3. Bathe the face with cold water.
4. Hold smelling salts near the nostrils.
5. Keep people from crowding near.
6. When the patient regains consciousness, give him spirits of ammonia or hot coffee.
7. In epilepsy, place the patient on his back, open clothing at neck, put knotted handkerchief in mouth (to prevent biting of tongue), and let the patient lie until he desires to get up.

507. The Nervous System and the Work of the World. — As already noted, men move things by use of their muscles. The muscles are moved by nerves. How accurately these muscles move and how fast they move depend upon how well the nervous system has been trained. Education trains the cerebrum to think. Drill trains the cerebellum and the medulla to act quickly in all conditions and to perform acts always the same way under the same conditions. This is the great value of habit formation. To preserve the body when injured or to prevent injury, habits of action must be learned early. To keep the nervous system in a high state of efficiency one must leave stimulants and narcotics alone. It is by the efficient men and women that the best work of the world must be done.

SUMMARY

All work is done by *muscles* moved by *nerves.* Many of our acts are *voluntary* and purposeful, others are *automatic* and useful in producing skill and quickness and in protecting the body.

The *brain* is the seat of *voluntary acts*, of the *sensations*, and of the *will.* Here also in the lower centers are located all the actions necessary to carry on bodily processes. By training, the *central nervous system* can do wonderful feats of skill. *Habit formation* is necessary to make life worth the living.

The organs of the body are connected with the brain and other

nerve centers by *neurons* composed of *nerve fibers* divided into *axon*, *dendrites*, *branches*, *sheath*, and *nucleus*. These nerves are either *afferent* (sensory) or *efferent* (motor). At about 15 years of age this nerve system becomes highly developed and is most easily injured. It is then that bad habits are most likely to be formed.

Alcohol as a *poison* and *narcotic* as well as a *stimulant* causes the slow destruction of the nerves, resulting in a loss of mental efficiency. Tobacco as a narcotic reduces the mental powers, stunts the growth, affects the manhood and manners of people using it, and leads to loss of will power.

Right habits of action are life savers in cases of emergency. To know what to do and how to do it, with a body trained by habit to act quickly and efficiently, may often enable one to prevent accidents of a serious kind. The dangers of traffic, fire, wounds, severe cuts, sprains, fractures, drowning, fainting, and epilepsy are all considerably lessened by training oneself to meet such emergencies promptly and effectively. Habits must be formed, if the mind is to be relieved of the heavy strain which our busy life would otherwise put upon it.

Remember that :

1. The nervous system is the engineer that runs the human engine.
2. The nervous system is a highly developed and sensitive part of the human engine. It comes in constant contact with every one of the primary factors of our environment and keeps us informed of what is going on about us.
3. The formation of right habits is the only proper method of developing ability to do things in an easy and efficient manner.
4. A careful avoidance of alcohol and tobacco is necessary to insure an efficient body, because these substances are the arch enemy of the nerves and muscles.
5. A careful training of the nervous system to act involuntarily under certain conditions is the only safe method of avoiding accidents and injuries to the human engine.

THOUGHT QUESTIONS

1. A deserter from the army went to work as a waiter in a restaurant. An officer in search of him, desiring to find out if the waiter was an army man, shouted to this waiter as he was carrying a tray of dishes " Attention ! " The waiter dropped the tray and came to attention. Explain why he did this.

2. Explain why one's mouth often waters at the sight of an orange or other fruit.

3. Explain the nerve action which occurs when one sees a pin on the floor and picks it up.

4. Why do you not think about your steps? Why is this dangerous to you as well as beneficial?

5. Give some of the advantages of a habit which you have noticed in your own everyday experiences.

6. Why is a lazy boy in grammar school likely to be lazy in his high school?

7. Why is there an "awkward" squad at every army post? What causes a reduction in the number of men in this squad? Why are the men in this squad mostly raw recruits?

8. How do you get your knowledge of what is in this book? Explain.

9. What are "unskilled workmen"? Why do they draw a lower wage than skilled workmen?

10. Why is habit formation more important to-day than at any time before?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Betts. Mind and Its Education. D. Appleton and Co.
Gulick. Emergencies. Ginn and Co.
Hawkesworth. The Workshop of the Mind. Century Co.
Loosmore. Nerves and the Man. Doran.
O'Shea. Tobacco and Mental Efficiency. The Macmillan Co.
Riggs. Just Nerves. Houghton Mifflin Co.
Walsh. Yours for Sleep. E. P. Dutton and Co.
Williams. Healthful Living. The Macmillan Co.

PART VII

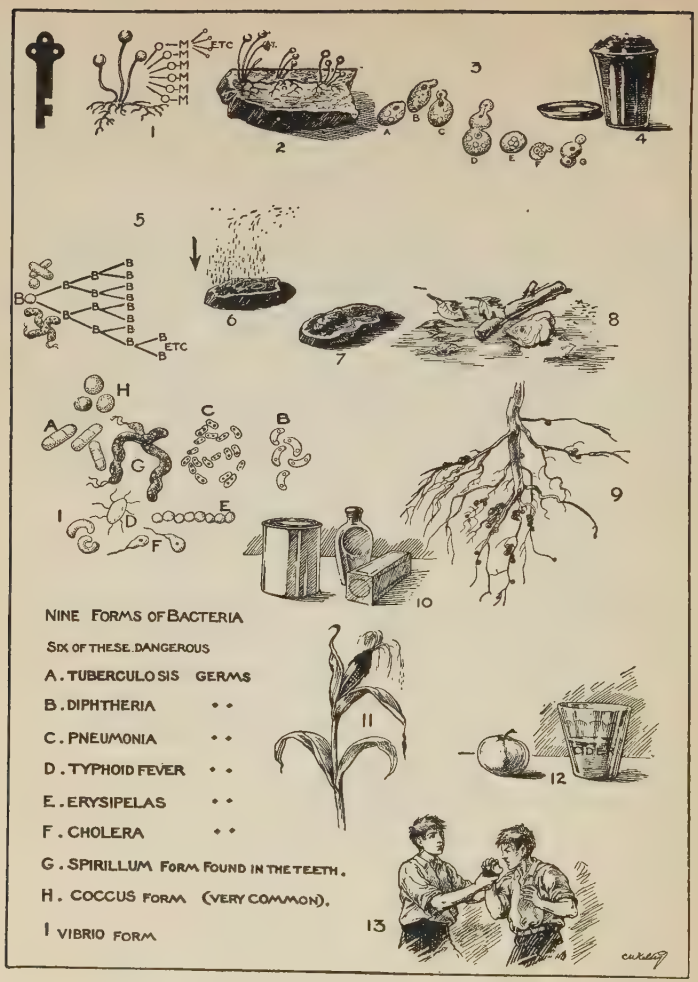
THE WORK OF PROTECTING THE HUMAN BODY FROM THE DANGERS IN ITS ENVIRONMENT

Law governs the sun, the planets, and the stars. Law covers the earth with beauty and fills it with bounty. Law directs the light and moves the wings of the atmosphere, binds the forces of the universe in harmony and order, molds every form of life.
— Tappan.

You have learned how the factory engine and the human engine are built to do their work and how they actually do that work. But to do their work efficiently both kinds of engines need care and adjustment. Moreover, the human engine is subject to dangers in its environment which the steam and gas engines entirely miss.

When men live in houses and depend upon food from distant places, the danger from contamination of their foods and their homes is great. When men live in large communities for the purpose of working in large factories, the danger from epidemic diseases, sewage water, drinking water, and milk is great.

Bacteria and other organisms cause disease and death. It is well, therefore, to know something of these dangers, where they may be found, how prevented, and how controlled in the home and in the community. The next three chapters will endeavor to give you valuable information on this most important subject.



KEY PICTURE 21.—THE WORK OF MICROÖRGANISMS.

1. How molds reproduce. Each spore (O) produces a new mold (M). What does each new mold do? 2. Molds growing on bread and spoiling it for human use. 3. Yeast cells. 4. A jar of fruit spoiled by yeast causing it to "work." What was wrong here? 5. Plan of reproducing in bacteria. Can you explain it? 6. Bacteria in the air falling on meat. 7 A bacterium (much enlarged) feeding on the meat. Juices pass out into the meat, digesting it and making it slimy. This slime is then absorbed into the bacterium as food. 8. Bacteria acting as scavengers. What do they do to the leaves, fish head, and stick? 9. Root tubercles on the roots of clover. In these tubercles live bacteria which "fix nitrogen" and make it usable to the plant. 10. Sealed foods. 11. Corn smut. A fungus growth (mold). 12. Cider, the juice of the apple. What causes the cider to ferment? 13. What is wrong in the actions of the boys in this picture? Explain fully.

CHAPTER XXI

MICROÖRGANISMS AND THEIR WORK

Why has not man a microscopic eye?
For this plain reason: man is not a fly.
Say, what the use, were finer optics given,
T' inspect a mite, not comprehend a heaven.
— *Pope.*

Nowadays the serpent that bites man's heels is in nine cases out of ten microscopic. — *Professor J. Arthur Thompson.*

Here you come to the little things of the world. What do you know about bacteria? Did you ever see one? Did you ever see your mother put yeast in the bread dough? Why did she put the yeast in the dough? Have you ever tasted sour milk? What made it sour? Did you ever see moldy bread or cheese? What made it look that way? What conditions make these little things grow? What stops their growth? Do any of these little things help man in his work? Why are liquid foods dangerous? How can these little things be controlled in your home? You will find out how this is done in the following pages.

Some Practical Questions :

1. How has the general use of refrigerators reduced the death rate?
2. Why should bread be kept in a bread box where it is dry?
3. What is the advantage of having groceries wrapped in sealed boxes or in airtight tins or glass jars?

4. Why should school classrooms and especially school lunchrooms have their floors cleaned and oiled frequently?

5. What is the value of having clean dishes and cooking utensils at all times?

Home Problem. — Take a small portion of a loaf of bread which has been kept fresh by paraffin paper and very slightly moisten it. Set it in a cool dark place. Wrap a second piece of the bread in the paraffin paper and place close beside the moistened bread. Let them stand for about two days; then examine both. Now tell the advantages of the paraffin paper.

Field Problem. — While eating in a restaurant, note if you find any cracked cups or plates. If one is given you with food, refuse to use it. In some states laws prohibit the use of cracked eating utensils in restaurants and hotels. Explain.

1. Why Foods Must Be Protected

508. The Care of Foods. — When you buy a pound of meat at the market, the butcher goes into the cooler, brings out a large piece of meat, cuts off a small portion, and at once returns the remainder to the cooler. You hurry home with your meat and put it in the refrigerator. As soon as possible this meat is prepared for eating by the use of heat. It is then carried to the mouth and after reaching your stomach and intestines it becomes alive with invisible organisms which we call bacteria (băk-tē′rĭ-ȧ).

(Key) **Demonstration 53:** ***Problem: Do air, water, and food contain living organisms?***

Materials: A piece of beef the size of a quarter; a few pea seeds which have been cooked; a little water from the faucet; and four Petri dishes containing prepared agar[1] (Fig. 304).

[1] Petri dishes can be procured through your druggist or from any biological supply house for about 12 to 15 cents each.

Agar can be purchased from your druggist at small expense. About 3 ounces is sufficient. It can be prepared as follows: Melt 10 g. (grams) of agar in 1000 cc. of hot distilled water. Add 10 g. of salt, 10 g. of peptone, and 10 g. of Liebig's beef extract. 100 g. of French gelatin may be substituted for the agar. This material can be filtered through absorbent cotton into sterilized bottles, sealed, and kept until needed. To prepare for use melt the pre-

Method: Expose one Petri dish to the air of the schoolroom two minutes and close. Place a very small piece of the meat and two pea seeds in a second dish, press them against the surface of the agar, then remove them and close the dish. Place a few drops of faucet water in the third dish and close. Keep the fourth closed as a control. Set the whole aside for 48 hours.

Observations: Note each dish. Do you find bacterial colonies present, indicated by rounded creamy masses on the surface of the agar? Each of these colonies contains millions of bacteria. Which has the greatest number of colonies? Is there any reason for this? Explain. Do the colonies differ in size, color, and shape? What

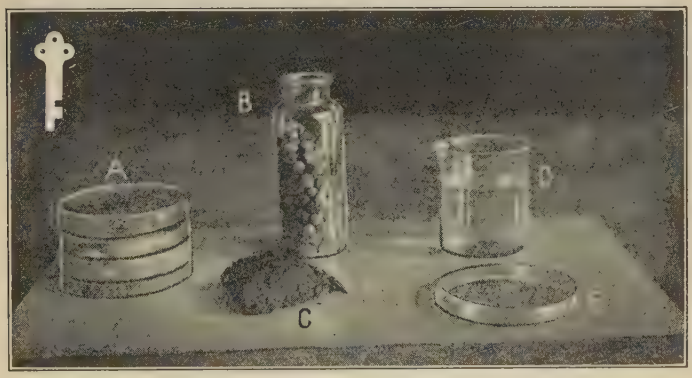


FIGURE 304. — (KEY) DEMONSTRATION 53.

A, Petri dishes containing prepared agar; **B**, cooked pea seeds; **C**, cooked beef; **D**, beaker of faucet water; **E**, Petri dish containing prepared agar used as a control.

would this indicate? Remove a very small bit of one of these colonies with a needle, mount with water on a glass slide, and observe under a compound microscope. Do you note any movement in the field? Can you actually see moving bodies? Can you make out the shape of any of them? These moving objects are the individual bacteria which feed upon the agar and produce the creamy spots. (Save one of the bacterial colonies for Demonstration 54.)

Conclusion. — Do water, air, and food contain living organisms? Give proofs by showing sketches of the forms you observed. Write a full account of the above in your Science Discovery Book.

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pared agar, standing the bottle in a double boiler. Then run the agar into sterilized Petri dishes and cover while hot. Just enough should be poured into each dish to cover the bottom of the dish.

509. Forms of Bacteria. — Bacteria are one-celled plants which are unable to make their own food and so must get it from other organisms or organic material. There are three general forms, — the ball or period-like, called the *coccus* (kŏk′ŭs); the rod-like or *bacillus* (bȧ-sĭl′ŭs); and the cork-screw-like, called the *spirillum* (spī-rĭl′ŭm). The spirillum, especially, can move with great speed through liquids, by means of tiny whip-like structures called *flagella* (flȧ-jĕl′ȧ). Many other forms move slightly, while some are entirely motionless. (See Key Picture 21.)

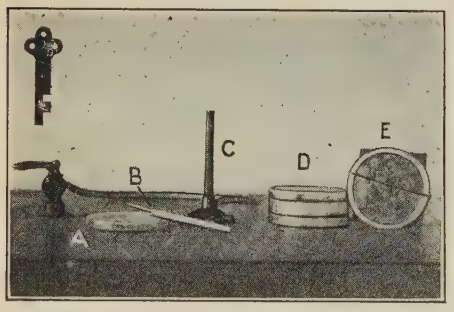


FIGURE 305. — (KEY) DEMONSTRATION 54.

A, control; **B**, needle; **C**, Bunsen burner; **D**, prepared Petri dishes containing agar; **E**, bacterial culture.

All must have moisture in order to thrive, some must have oxygen and are for this reason called *aërobic*, while others need no free oxygen, but can derive it from the compounds upon which they work. Such forms are called *anaërobic*. When dried out, some bacteria form *spores*, which float about until they come in contact with moist conditions again. (See Key Picture 21.)

(Key) **Demonstration 54**: ***Problem: What conditions are favorable and what unfavorable to the growth of bacteria?***

Materials: Six Petri dishes prepared with agar; a dissecting needle; a test tube; a Bunsen burner (Fig. 305) and the dish containing the bacterial colony saved from Demonstration 53.

Method: Inoculate each Petri dish with some bacteria by dipping the needle into one of the bacterial colonies and smearing the matter over the surface of the agar in each dish. Or shake the bacteria from the needle into a test tube containing a little water. Pour this on the agar. Number each dish (1 to 6), cover and set aside as follows: Place one dish in strong light in temperature of

65° F. Place another in the dark, with the same temperature. Place a third in a temperature of 85° F. and in the dark. Place a fourth in a refrigerator and in the dark. Place a fifth in a moist, dark place with temperature at about 70° F., and the sixth in a dry, dark place at the same temperature. Examine each after 48 hours.

Observations: Compare dishes 1 and 2. Compare 3 and 4. Compare 5 and 6. Draw your own conclusions as to what conditions are favorable to the growth of bacteria. What conditions are unfavorable to the growth of bacteria?

Practical Applications: Determine how the conclusions you have drawn here might be used to great advantage by your mother in the home. The knowledge gained here may be the basis of your health. For this reason write up the record in full in your Science Discovery Book.

510. Other Small Organisms, Yeasts and Molds. — You must not think that bacteria are the only small organisms that spoil foods. There are many others, some of which are very commonly known. It is now possible for you to work out a very interesting experiment to show some of these organisms. Would you like to know just how yeast and molds act upon foods (Key Picture 21)?

Suggested Experiment. — Buy a cake of Fleischmann's yeast, get a two-ounce bottle, some sugar, some syrup, a small piece of bread, a Petri dish, a pipette, and some limewater. Fill the bottle half full of warm water and dissolve a teaspoonful of sugar in it. Then, put a piece of the yeast, about the size of a marble, into it. Cork and set in a warm place over night. Moisten the bread slightly, place on a saucer, and after it has been exposed to the air of the room for one hour, invert over it a glass tumbler. Pour a little of the syrup into the Petri dish and leave exposed to the air for 48 hours.

Note if anything has happened to the cork in the bottle during the night. Smell of the mouth of the bottle. What do you think is coming from it? Draw off some of the air from the bottle and run it through the limewater. Result? Conclusion? Take a very small amount of the liquid from the bottle and place under the compound microscope. Note the tiny egg-shaped bodies. These are yeast cells. Each consists of a cell wall, protoplasm, and a large, translucent spot called the *vacuole* (văk'ū-ōl) filled with cell sap. Note the buds growing from some. The cells reproduce by budding (Key Picture 21).

Now observe the syrup. Smell of it. Can you determine what is in it? What might have produced this smell in the syrup? What effect does yeast have upon foods containing sugar? Is the syrup now fit for use? Explain. Sketch several yeast cells. Label.

Examine the bread. What do you see upon its surface? Describe it. This is bread mold. Smell of the bread. Is the bread fit for use? Is there more than one kind of mold on the bread? Explain. Examine some of the mold under the microscope, noting its structure, how it grows into the bread, and how it reproduces. Sketch several filaments, labeling the parts.

511. Man's Invisible Foes. — All about us in the air, water, food, and earth, and even in our own bodies are multitudes of invisible foes. Some appear in visible form, like the molds and mildews, and grow upon bread, damp leather, stoves which have been recently blacked, and fruits.

The yeasts, too small to be seen, make their presence known in the rising of dough in bread-making and in the spoiling of all foods, not properly sealed, containing sugar in a more or less liquid state. Finally there are the bacteria, so small that 1000 of them could comfortably rest side by side across the head of a pin. If this circle ◯ were magnified enough times to become a body as large as the earth, some bacteria would have to be magnified the same number of times to become the size of the circle. Try to comprehend just what this means. You may conclude, then, that yeasts and bacteria are extremely small plants, are found almost everywhere, are spread by spores or buds, and spoil foods.

512. Parasites and Saprophytes. — Microörganisms live on plant and animal tissues, both dead and alive. All organisms which live on or at the expense of other living organisms are called *parasites* (păr'ă-sīts). Examples of parasites are bacteria in the lungs of a man, the wheat rust, corn smut, mildew, and the chestnut blight which has practically destroyed all of our chestnut groves in the East. All organisms which can live upon dead organic matter are called

saprophytes (săp′rŏ-fīts), and it is with this class of plants that we are most interested because they thrive upon our foods, which, of course, are largely dead products of plants and animals (Fig. 306).

513. What Microörganisms Like in Organic Matter. — (*a*) *Molds.* These are black, brown, blue, or *non-green* plants which ordinarily attack foods used by man. The substance in flour or bread which gives it a sticky feeling, called *gluten*,

FIGURE 306. — SHELF FUNGUS GROWING ON A FALLEN TREE.
These plants get their food directly from the tree and break it down into soil and gases.

is protein in nature. Molds like this substance, but it is not in soluble form in either the flour or bread. It must, therefore, be digested or changed into a soluble condition. As the mold spores light upon the bread, they begin to throw out threadlike branches called *hyphæ*, which give off a digestive juice or enzyme into the bread, changing the gluten to soluble proteins. These are then absorbed by the mold and transformed into protoplasm; growth results, wastes are given off, and the bread is spoiled for human use. Other nutrients also in the bread are digested and absorbed by the molds. What the mold gains,

you lose. You may get some good food by eating the mold itself; this is done when certain kindred forms, such as puff balls and mushrooms, are eaten. Limburger, Rochefort, and other cheeses get their flavor from molds, which are thus valuable. Yet, in general, molds are economically expensive to us (Key Picture 21).

(*b*) *Yeasts.* Your experiments have shown that yeasts feed on sugar. They attack this plant product whenever it is found in a more or less liquid condition, breaking it up into alcohol and carbon dioxide. The effect of this action upon the sugar solution or food we know as *fermentation* (fûr′mĕn-tā′shŭn), a process in which alcohol and heat are released and food is spoiled. It is very important, then, that all preserved fruits and vegetables in which sugar has been used should be tightly sealed to prevent the entrance of the yeast spores (Key Picture 21).

Demonstration 55: *Problem: What effect do bacteria have on foods?*

Materials: A wide-mouthed bottle with stopper to fit and a small piece of raw meat (beef) about the size of a thimble.

Method: Place the meat on a piece of paper in the bottom of the bottle. Leave exposed to the air for about 24 hours. Now put the stopper in the bottle tightly and leave for a second 24 hours.

Observations: Observe the appearance of the meat through the side of the bottle. Has it changed in any way? Does it look partly liquefied? Does it look slimy? Now open the bottle and smell of its contents. What do you notice? What has happened to the meat? What caused the meat to spoil? What two effects do bacteria have upon meat?

Conclusion: What is it? Write this demonstration out in full.

Note. — To make sure of your conclusion place a little of the slime on a glass slide, dilute with a drop or two of water, and examine under the low power of the microscope. Report your observations in your Science Discovery Book.

(*c*) *Bacteria.* It was not until 1683, when Anton van Leeuwenhoek (lā′vĕn-ho͝ok′), a Dutch weaver, and a grinder of lenses as a pastime, perfected the microscope, that people were able to see these organisms. And it was not until

1850–1860 that any real connection between bacteria and disease was even suspected. Then Louis Pasteur, a French scientist, and later Robert Koch, a German experimenter, gave to the world definite knowledge of the effects of bacteria upon other organisms, and the science of bacteriology was developed.

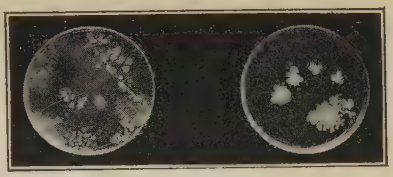


FIGURE 307A. — BACTERIAL COLONIES.

A fly walked on the agar in the left-hand dish. A boy touched the agar in the right-hand dish with the tips of thumb and fingers. Explain.

The slimy, repulsive appearance of spoiling meat and its most offensive odor are always a sign of the presence of bacteria. (See Key Picture 21.) The severe illness which sometimes follows the eating of canned vegetables, meats, olives, fish, raw oysters, and ice cream, especially when eaten in warm weather, is frequently caused by this action of bacteria as they work upon foods (Figs. 307a and 307b).

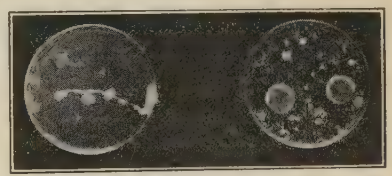


FIGURE 307B. — BACTERIAL GROWTHS.

A human hair (left) was placed in the agar. Agar exposed to the air for two minutes (right). Explain.

The constant danger from such foods is shown below.

HUNDREDS OF HIGH SCHOOL STUDENTS MADE ILL BY PTOMAINE POISONING AFTER SCHOOL LUNCH

Several hundred students of the Woodlawn High School here were stricken with ptomaine (tō′mā-ĭn) poisoning after their lunch eaten at the school lunch room today. All physicians in the city were called upon to give first aid treatment. A thorough investigation will be made at once.

— *New York Times*
Sept. 29, 1922.

2. Our Invisible Friends

514. The Work of Yeast in Bread and Alcohol Making. — Many industries owe their existence and success to yeasts, molds, and bacteria. It is but justice to these lowly organisms that we discuss their good qualities as well as their bad ones. Yeast is a good plant with which to begin. It is mixed with bread dough in which is placed some sugar and water; heat (75° F.–85° F.) is applied, and the yeast cells work and grow very rapidly, giving off large quantities of alcohol and carbon dioxide. The gas in escaping raises the dough, making it porous and light. When the bread is baked, the yeast plant is killed, the gas and alcohol are driven off, and the bread set as we find it in a loaf (Fig. 308). Without the yeast we should have to eat unleavened bread or "hard tack." For the production of fuel alcohol, bay rum, extracts, and certain medicines, yeast is invaluable.

515. Bacteria in Food Manufacture. — Milk, when allowed to stand, soon teems with bacteria, the most common being *lactic* (lăk′tĭk) *acid* bacilli. These organisms act upon the *casein* (kā′sē-ĭn), a protein substance in the milk, and change it into a firm curd; the milk sugar is changed into lactic acid. The presence of this acid makes the milk curdle. It is from this curd that cheese is made. It is from the soured cream that the best flavored butter is made. Milk is often made to sour by the addition of *rennet* (rĕn′ĕt), a digestive juice from the stomach of a calf, which soon forms a curd. Junket tablets are made partly of dried rennet.

516. Bacteria in Leather and Linen Manufacture. — In the manufacture of leather the skins of various animals are used. The hair is removed from the hide by allowing the hide to putrefy slightly through the action of bacteria. This putrefaction also helps to make the leather soft and pliable.

In the production of linen, the stem of the flax plant is used (Fig. 309). The fibers are tough and stringy and are of no value until made soft and pliable so that they can be

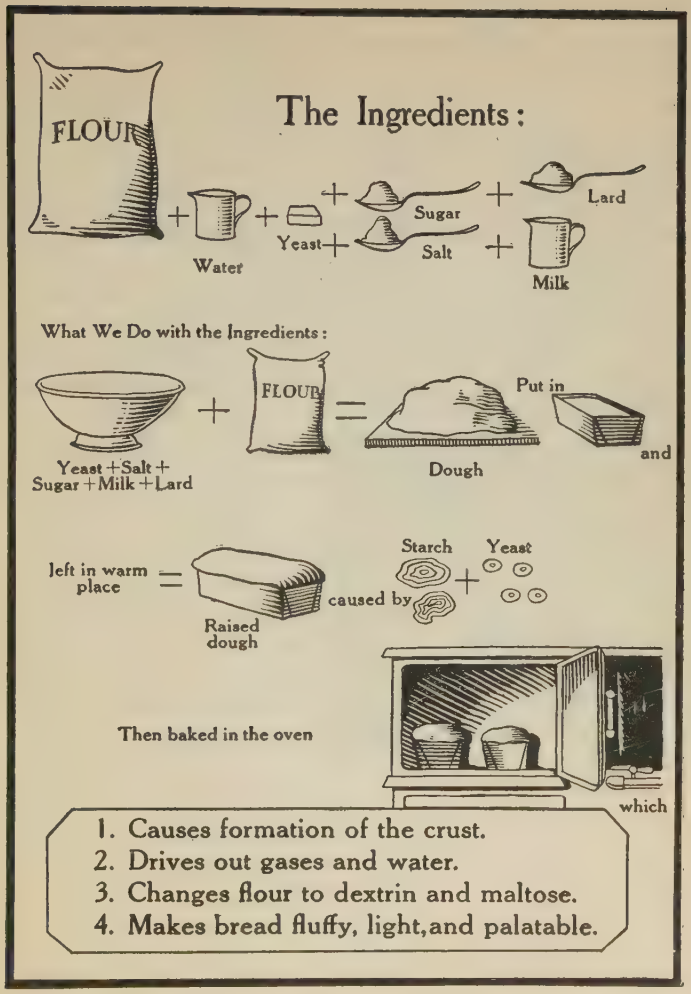


FIGURE 308.—THE STORY OF BREAD MAKING.
Learn this story and tell it correctly.

split into threads and woven into cloth. This is done by immersing the flax in stagnant water until the action of bacteria partly rots or decomposes it (Fig. 309).[1] It is then easily broken up into threads, specially treated, spun, and then woven into fabrics. Linen is probably the oldest fine fabric known and it receives its value through the action of bacteria.

517. Bacteria as Scavengers. — When a plant or an animal dies, the strong odor soon coming from it is due to the breaking down of the protein compounds and the releasing of hydrogen sulphide, a gas. Such a process is decomposition and is brought about by bacteria. Eventually, the animal or plant is turned completely back into the soil and gases from which it was originally made. Dead trees, leaves, animals, human beings, garbage, and manures are all acted upon in the same way. In fact, the farmer depends largely upon these bacteria for his crops, for they alone can make animal manures fit for use by plants. Decomposed manures release into the soil the ammonia compounds so helpful to plant growths (Key Picture 21).

FIGURE 309. — FLAX-RETTING.

The flax is being submerged in water to be rotted (retted) by the action of bacteria. What do the bacteria do here?

518. Bacteria and Fermentation. — Yeasts are not the only organisms which can cause fermentation, however.

[1] Sponges are prepared for the market in much the same way, except that they are allowed to decompose in the air.

Any organism that can produce a ferment can bring about fermentation. Even putrefaction is a form of fermentation. In no place is this process better shown than in the formation of vinegar. Apple juice contains sugar. We call this juice cider. When yeast gets into this juice, alcohol is formed. Explain. This alcohol, when attacked by a certain kind of bacteria, is changed into acetic acid. The cider has been changed to vinegar. The thick brownish material at the bottom of the vinegar bottle is the "mother," a thick mass of bacteria which make the change in the alcohol.

Again, the peculiar odor of butter is due to the action of bacteria on the nutrients in the butter resulting in *butyric* (bū-tĭr'ĭk) acid. The different varieties of cheese owe their flavors and prices to bacteria. Sauerkraut is given its flavor by the action of bacteria; ensilage (ĕn'sĭ-lāj), which cows like so much, is the result of bacterial fermentation in the corn stalks cut off from air in the silo. The odor of tobacco is primarily due to partial decomposition of the tobacco leaf tissues by bacteria.

U. S. Dept. of Agriculture.

FIGURE 310A. — ROOT TUBERCLES ON THE ALFALFA PLANT.

Note the tiny bulb-like objects (tubercles) attached to the roots. Here live millions of bacteria, which "fix" the nitrogen and make soil fertile.

519. Bacteria and Soil Fertility. — Fertile soil is always full of bacteria. Where do they come from? Sterile or worn-out soils can be made fertile by the addition of bacteria. How is this done? A careful examination of any clover plant root will show tiny round masses or swellings called *nodules* (nŏd'ūlz) or *tubercles* (tū'bĕr-k'lz), in which large numbers of bacteria live. The bacteria are able to take the nitrogen directly from the air and, by com-

bining it with other substances, produce nitrogenous compounds (nitrates) for the use of the plant (Fig. 310a). Thus, we have the *fixation of nitrogen* by bacteria. So, raising a crop of legumes is the surest way of insuring a good crop of corn on the same plot of ground. Explain.

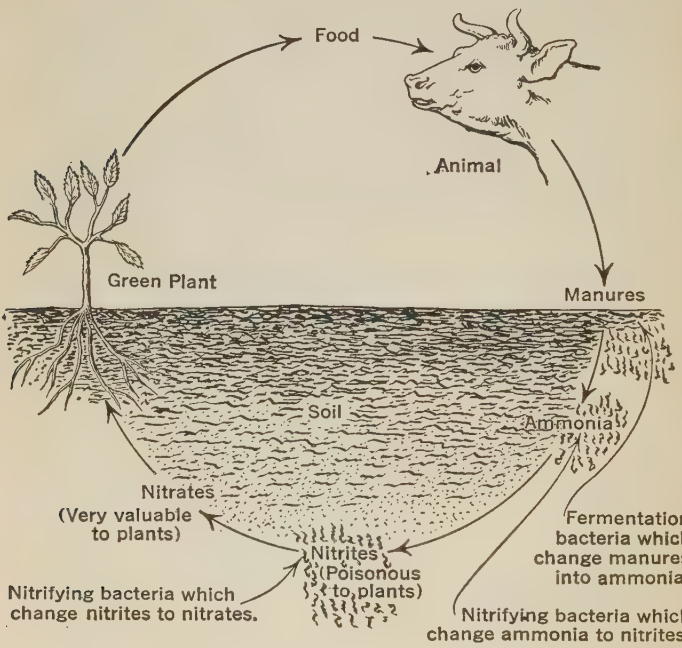


FIGURE 310B. — THE NITROGEN CYCLE.
Explain this picture. (See section 519.)

The manures placed in the soil by the farmer are so acted upon as to produce a final product of great value to the plants. This is done by three sets of bacteria: (1) The putrefactive forms change the manure to simpler compounds (ammonia); (2) a second set changes the ammonia to *nitrites*; (3) the nitrites are changed to *nitrates* by a third set of bacteria. This is called *nitrification* (nī′trĭ-fĭ-kā′shŭn)

or *nitrate making*. Thus are organic compounds made useful to plants through bacteria (Fig. 310b).

3. Our Invisible Foes

520. Bacteria and Disease. — On the other hand, bacteria are responsible for the deaths of from one half to two thirds of all persons who die in the world every year. They are man's invisible and terrible foes.

They feed upon our tissues which they assimilate as food, oxidizing it, and giving off wastes which are *toxins* (tŏk'sĭnz) or poisons to the animal receiving them. These toxins are the cause of many diseases in man.

521. How Bacteria Enter the Body. — These organisms fall into or are forced into natural body openings, such as the mouth, nose, eyes, ears, or wherever a mucous membrane is exposed to the air. When a cut or bruise is made in the skin, which is the natural defense of the body, bacteria may be brought immediately into the blood flow and among the cells, and disease may follow quickly. The conditions in either method of entering are finally the same, — a warm, dark, moist place where growth is sure and rapid. The body is an excellent breeding place for many microörganisms. Therefore, extra precautions must be taken to protect and defend it from their entrance. Many persons have the unpleasant habit of spraying other people with sputum as they talk or sneeze or cough, thus throwing bacteria directly into the mouth and nose. All such persons are a real menace to the health of the community. See to it that you do not form this harmful habit. Liquids, especially milk and water, are likely to contain myriads of bacteria originating from the hands of people who are sick and none too clean in their personal habits. Some persons are even known to carry disease germs, particularly those of typhoid fever, and to give this disease to other people, though they do not have it themselves. Read the newspaper item on the following page.

OWNER OF BAKERY TYPHOID CARRIER

Bakery Worker Arraigned for Handling Food After Being Forbidden

Had the Disease in 1906

Case Resembles the Famous One of "Typhoid Mary" — 119 other typhoid carriers now under observation.

— *New York Times.*

522. Why We Can Foods. — If a food is free from microorganisms when put into a container and if the container is really air tight, such food will never spoil.[1] A common method of preserving foods begins with boiling the glass jars or containers. Why? This is called *sterilization.* The food to be preserved is then cooked, and put while hot into the container, which is then sealed. Give two values of the cooking and tell why the food is put into the container while hot. Rubber rings separate the glass top from the jar. Explain. The outside of the jar is then wiped dry and the jar is inverted for some time on a piece of white paper or oilcloth. Why? If moisture is found later on the paper, what conclusion must be drawn (Fig. 311)?

Cleanliness in this method is the only guarantee of success, — clean containers, clean food, clean water, clean utensils, and clean hands. Full directions for using this method may be secured in Farmer's Bulletin No. 839. This bulletin may be obtained by writing to the Department of Agriculture at Washington, D. C. (Key Picture 21).

523. Why We Pickle and Preserve Foods. — Some of us have seen the process of pickling going on in our homes in

[1] The writer had the rare privilege of seeing and handling, in 1922, a flask of beef broth (a food much desired by bacteria) which had been sealed by Louis Pasteur in 1862, sixty years before. The broth was as clear and as fresh as the day it was placed in the flask. This flask is now in the possession of Dr. LaPlace, a surgeon of Philadelphia and a former pupil of Pasteur in Paris. Can you tell some things that this sealed flask proves about bacteria and foods?

the summer or early fall. At that time cucumbers are picked, thoroughly washed, then laid down in a strong brine, and covered in an earthen jar or canned in glass jars. Likewise, corned beef is immersed in brine. Sauerkraut also is treated in the same way and even butter is salted to increase its keeping qualities. Explain this fully.

Fruits are often candied and thus preserved. How does this process keep out the bacteria? If the fruits become moist, would bacterial growth begin? Explain fully to your class and to your family at home.

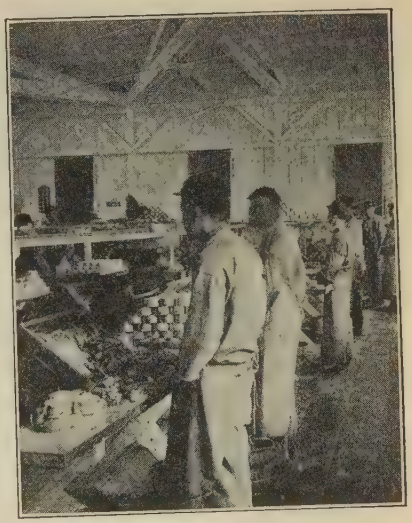


FIGURE 311. — A CANNING FACTORY.

Here salmon is canned and the cans sterilized with steam after being sealed. Explain fully this statement.

524. Why We Dry Foods. — It used to be a common sight years ago to see long strings and festoons of dried apples hanging from the rafters of the attic in the average farmhouse. These were used in the winter to make pies. It is probably true that this custom was not based upon knowledge of bacteria as bacteria, but it was a sensible plan, nevertheless. To-day, the evaporating factories do this work. What was the advantage of hanging the apples in the attic? Bacon, dried beef, and meats of all kinds are kept by the same method.

525. Dangers in Liquid Foods. — Bacteria are especially fond of liquid food, because they can easily digest it before absorbing it. Milk is the best medium for their growth. This liquid is most easily contaminated when exposed to air even

for an instant, when placed in unclean receptacles, when touched in any way with the hands, or when allowed to remain warm too long after coming from the cow.

The great danger in such exposure is from bacteria which cause disease. Diarrhea, dysentery (so fatal to many infants), tuberculosis, diphtheria, typhoid fever, and scarlet fever are all frequently traced to milk.

FIGURE 312. — HOW MILK IS SHIPPED TO THE CITY.
How is the milk kept sweet? What demonstration shows you a principle that is applied here?

For this reason milk is brought to your door in capped bottles which have been scalded, filled with *pasteurized* (pȧs'tēr-īzd) milk, and kept continually on ice after leaving the pasteurizing plant. Pasteurization kills about 90% of the bacteria in the milk and ice keeps the remaining 10% very inactive. It is the housewife's task to see that no more bacteria get into the milk before it is consumed.

(Key) Demonstration 56: ***Problem: How is milk pasteurized and how is it affected by the process?***

Materials: Several glass beakers; some raw or unpasteurized milk; thermometer: a bunsen burner; an iron tripod; and three prepared Petri dishes (Fig. 313).

Method: Put equal portions of the milk in three separate beakers. Label them 1, 2, and 3. Leave 1 exposed to the air for 48 hours. Heat the milk in 2 over the flame, bringing it to a temperature of about 145° F. for about 20 minutes, but never exceeding that temperature. Set aside for 48 hours, exposed to the air. Boil the milk in 3 for about 10 minutes. Set aside, exposed for 48 hours.

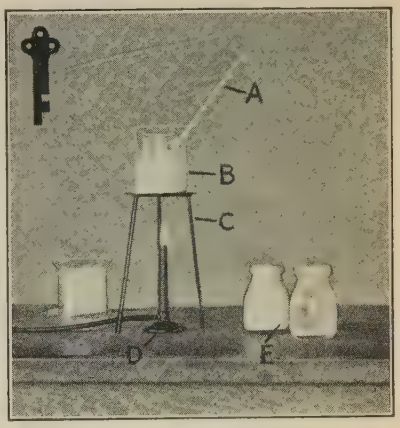


FIGURE 313. — (KEY) DEMONSTRATION 56. Why is the thermometer used? Why are Petri dishes used in this demonstration?

Observations: What effect does the boiling have upon the appearance of the milk in 3? Does the heat change the milk in 2? Examine all three beakers after 48 hours. What has happened to the milk in 1? What caused it to sour? Are the milk in 2 and the milk in 3 affected in the same way? Explain. Taste the milk in each beaker. Do the milk in 2 and the milk in 3 taste the same? Can you explain the difference?

With a medicine dropper place five drops of the milk from 1 in a Petri dish. Label it 1. Do the same with the other beakers and Petri dishes, labeling them 2 and 3. Lay away for 48 hours. Then examine under the compound microscope. Which has the most bacteria? the least? Are bacteria present in all three? Why is not all milk boiled to destroy all the bacteria?

Conclusion: How is milk pasteurized? How is it affected by the process? Give proofs for your answers.

526. Why and How Milk Is Pasteurized. — Pasteur discovered the value of heating foods to kill bacteria in them. This simple discovery has probably saved millions of lives. Pasteur found that by heating milk for about half an hour

to a temperature not exceeding 155° F., most of the bacteria in it are destroyed, without injuring the food value of the milk or destroying its flavor. If this milk is then placed in scalded bottles, sealed and packed in ice, it will keep for several days. The danger of its causing disease, which is especially great for infants, is very much reduced. Most cities now require that milk be pasteurized (Fig. 314).

FIGURE 314. — A PASTEURIZING PLANT.
Note how clean every part is kept. Explain this.

But we should remember that even pasteurized milk must be handled carefully in the home. Clean hands and clean receptacles are of first importance. The milk should be kept in the bottle in which it is delivered until needed for use. It should never be poured from the bottle until the top and sides of the bottle are throughly cleansed. Why? Finally, the home should have a good refrigerator, windows fitted with screens, and clean kitchen utensils.

527. The Importance of Cold Storage. — Since extreme cold makes it impossible for bacteria to increase, it follows that if meats, butter, eggs, and vegetables are kept in freezing conditions, putrefaction cannot set in. Until this fact was discovered, few in the eastern states knew what western beef was. Cold storage has completely changed our whole manner of living. One abuse has arisen from it,

FIGURE 315A. — AN UNSANITARY KITCHEN.

Name at least four things which are wrong here. Why are they wrong?

however. Much produce is put into cold storage in a poor condition or is kept in cold storage too long. To stop this abuse the Federal Government inspects the food in cold storage plants and forbids the keeping of produce in cold storage longer than a specified length of time, the period depending upon the kind of produce.

528. Cleanliness, the Final Word. — The kitchen should be the cleanest place in the whole house. It should be im-

maculate. Food and fingers carry disease germs and when they come into contact with one another, no one can foretell what the result will be, if either are unclean. Study Figures 315 a and b.

It follows, therefore, that clean water, good soap, a nail brush, and a nail cleaner are essentials of every home and

Good Housekeeping Institute.

FIGURE 315B. — A MODEL KITCHEN.

It is clean and wholesome. Name the essential things in this kitchen. Why is it a model kitchen?

should be unsparingly used by the housewife and all those handling the food of the family.

Dishwashing is an art, even though regarded by many as a drudgery. Hot water, plenty of soap, a good dish cloth, a scourer, and plenty of muscular energy are all necessary, if the complete protection of the family is to be assured. To this same end, all cracked plates should at once be discarded or destroyed. Why?

Finally, as to drying, it is best to place all dishes, after being rinsed in hot, clean water, in a drying rack. When hot, they will dry quickly by the evaporation of the water upon them, thus reducing handling and the possibility of contamination from the hands or soiled drying cloths. Above all,—everything must be *clean*.

SUMMARY

The foods of man are among the most favorable homes of *microorganisms* consisting of *bacteria*, *yeasts*, and *molds*. The yeasts and molds attack *sugary foods*, while bacteria feed chiefly upon *protein foods*. All these organisms are extremely small, float in the air, and alight upon foods which are exposed to the air. All grow best and most rapidly in the presence of *moisture*, *warmth*, and *darkness*. Bacteria grow best in liquid food such as milk.

The yeasts spoil foods by breaking them down into *alcohol* and *carbon dioxide* through the action of an *enzyme* or *ferment;* the molds break down the proteins of bread and similar foods, giving them an unpleasant odor and taste; while the bacteria act upon the proteins in meat, producing *slime* and a strong, disagreeable *odor*.

Bacteria are valuable in leather and linen manufacture; in breaking down dead bodies into soil; in enriching soil by putting nitrates in it; and in fermenting cider to form vinegar. The yeasts are valuable in raising bread and producing commercial alcohol. The molds are valuable in the ripening of cheeses.

Some foods, especially meat and milk, may harbor bacteria which cause disease. To check their growth the conditions unfavorable to these bacteria are secured; these are light, heat, dryness, and the absence of air. Thus milk is pasteurized, kept cool, and handled in a special way. Solid foods also are kept free from bacteria by preserving with harmless substances such as salt, sugar, and vinegar; some kinds are canned and sterilized (vegetables); still others are best preserved by drying to keep out the water and thus the bacteria; finally, some are kept in cold storage where the microörganisms are kept inactive by the extreme cold. But the use of clean utensils, handled by clean hands, in clean homes, is the best preventive of ills which may follow from the use of foods. *Cleanliness* should be the watchword of every home in the handling of all foods.

Remember that :

1. Microörganisms are the chief cause of the destruction of food which would otherwise be used as fuel by the human body.
2. Many microörganisms are absolutely essential to the enrichment of soil, the destruction of dead organic matter, and the production of valuable foods and other products.
3. Certain microörganisms are the chief causes of disease, much of which is developed through the use of germ-laden food and liquids.
4. Science has developed very efficient methods of preserving foods and preventing the growth of microörganisms in them.
5. Cleanliness is the chief requirement in the home for the proper preservation of foods and the keeping them free from dangerous microörganisms.

THOUGHT QUESTIONS

1. Give several reasons for cooking foods.
2. Name several things that can be done to insure cleanliness of air in the home; of food in the home; of water in the home.
3. What conditions are necessary for the growth of molds? What can you do in the home to prevent their growth?
4. What is the value of a " control " in the study of yeasts and bacteria?
5. Why will watery meat spoil more quickly than relatively dry meat?
6. Why will dried beef keep indefinitely?
7. Why do we never need to take much care in keeping shredded wheat, cornflakes, crackers, flour, etc.?
8. Mention at least five ways in which disease germs may be carried.
9. " Cover up every cough and sneeze.
   If you don't you spread disease."

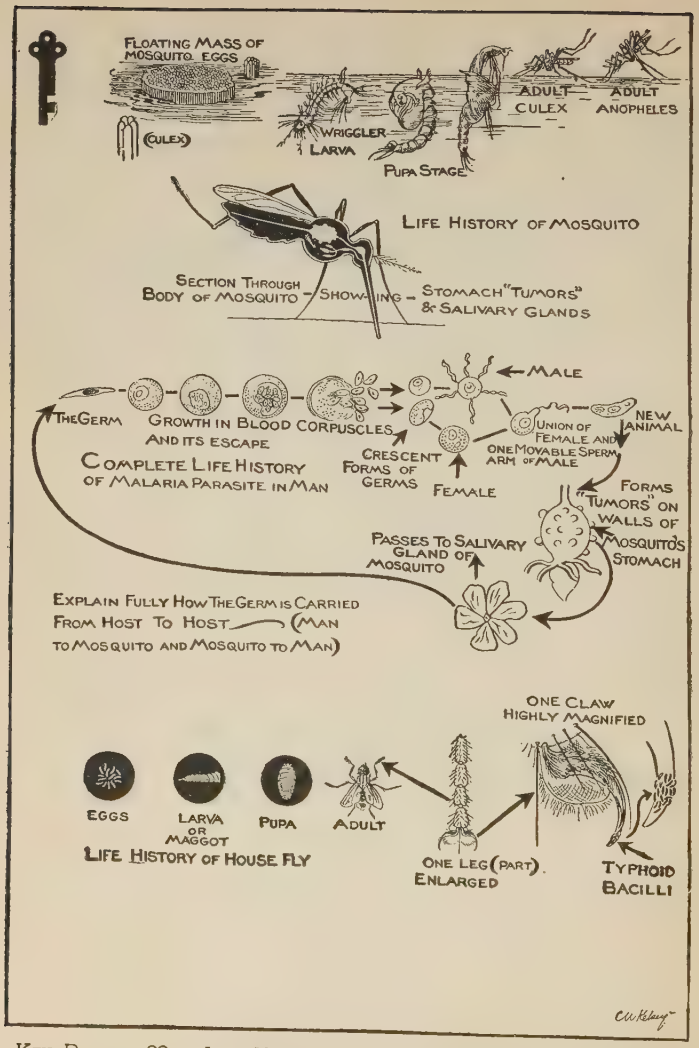
Explain this quotation and give the names of six diseases spread by this indecent habit.

10. Why do cities forbid spitting on the sidewalks?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Conn. Bacteria, Yeasts, and Molds in the Home. Ginn and Co.
Ealand. The Romance of the Microscope. J. B. Lippincott Co.
Kinne and Cooley. Foods and House Management. The Macmillan Co.
Kendall. Civilization and the Microscope. Houghton Mifflin Co.

McCubbin. Fungi and Human Affairs. World Book Co.
Presbrey Syndicate, New York City. The Book of Wonders.
Prudden. Dust and Its Dangers. G. P. Putnam's Sons.
Richards. The Cost of Cleanness. Wiley.
U. S. Department of Agriculture. Farmer's Bulletins. Washington, D. C.:
No. 375. Care of Food in the Home.
No. 413. Care of Milk and Use in the Home.
No. 841. Drying Fruits and Vegetables in the Home.


FLOATING MASS OF MOSQUITO EGGS
(CULEX)
WRIGGLER LARVA
PUPA STAGE
ADULT CULEX
ADULT ANOPHELES
LIFE HISTORY OF MOSQUITO
SECTION THROUGH BODY OF MOSQUITO SHOWING STOMACH "TUMORS" & SALIVARY GLANDS
MALE
THE GERM
GROWTH IN BLOOD CORPUSCLES AND ITS ESCAPE
CRESCENT FORMS OF GERMS
FEMALE
UNION OF FEMALE AND ONE MOVABLE SPERM ARM OF MALE
NEW ANIMAL
COMPLETE LIFE HISTORY OF MALARIA PARASITE IN MAN
FORMS "TUMORS" ON WALLS OF MOSQUITO'S STOMACH
PASSES TO SALIVARY GLAND OF MOSQUITO
EXPLAIN FULLY HOW THE GERM IS CARRIED FROM HOST TO HOST (MAN TO MOSQUITO AND MOSQUITO TO MAN)
ONE CLAW HIGHLY MAGNIFIED
EGGS
LARVA OR MAGGOT
PUPA
ADULT
LIFE HISTORY OF HOUSE FLY
ONE LEG (PART) ENLARGED
TYPHOID BACILLI

KEY PICTURE 22. — LIFE HISTORIES OF SOME OF OUR INSECT ENEMIES.

Study each part of the picture. Each tells its own story. Can you follow it? Try to raise some mosquitoes and flies. Compare with the stages here shown. Tell the story of the malaria parasite.

CHAPTER XXII

THE PROTECTION OF THE HUMAN BODY IN THE HOME

Ah, what avail the largest gifts of heaven,
When drooping health and spirits go amiss?
How tasteless then, whatever can be given!
Health is the vital principle of bliss,
And exercise of health. — *Thomson*

Man can never fool Nature; but Nature can easily fool man, because of his inability to understand her. Obey the laws of Nature and you ride to success. — *Wood.*

Why are insects in the home dangerous? Do you know? Do you know anything about the life history of the house fly or the mosquito? What do we mean by the life history of an animal or plant? Do you suppose that knowing the life history of an insect would help you in getting rid of it? Explain. Do you think that insects and disease are close companions? How does the body protect itself from disease germs? Do you know of any ways in which the human body is now aided by doctors to resist disease? What are some of the values of clothing in keeping people well? Explain. A careful study of these things in this chapter will teach you many interesting and practical things.

Some Practical Questions :

1. Why is it of value to know the whole history of insects which live about the home?
2. What is the most important reason for keeping insects away from foods?

3. What methods are used to exterminate household pests such as flies, water bugs, and ants?

4. Name at least 5 things that you can do to help the body ward off disease.

5. Give several reasons why the house fly is the most dangerous of household pests.

Home Problem. — Make a list of all the insects you have ever seen in and about your home. Find out some of the habits and the important facts about the life histories of each of these insects. Determine if these insects are harmful or useful and how. Write out in full your report and present it to the class.

Field Problem. — Make a special survey of the open lots in your neighborhood and discover the kind and number of receptacles in these lots which can hold water. Examine some of these receptacles, note if they hold water, and see also if they hold the larvae or " wrigglers " of mosquitoes. Are mosquitoes common in your neighborhood? Can you now account for their presence? How can you help to reduce the number of these insects in your neighborhood? Try out your plan and report to the class on the success of your venture.

1. Some Household Enemies

529. The Work of Household Pests. — Were man relieved of such pests as flies, mosquitoes, bedbugs, fleas, " cooties," clothes moths, cockroaches, croton bugs, disease-producing bacteria, rats, and mice, his health would be safer, his comfort greater, and his home a much pleasanter place in which to live.

For example, it is estimated that every rat in the United States works destruction to property at the rate of at least 2 cents each day. This means a total loss of enough money to pay 100,000 men working all the time to repair the damage done by these animals alone. Millions upon millions of dollars' worth of food is destroyed each year or made unfit for human use by insects and other animals of the home. How shall we go about the destruction of these pests?

530. The House Fly a Deadly Enemy. — The common house fly is directly responsible for over 100,000 deaths every year in the United States. Think what this means! Nearly

twice as many men as we lost in the World War are killed every year by flies! Flies are rapid fliers and seek every possible place where food can be found. (See Key Picture 23.) Now if you want to be a real scientific detective, the next experiment ought to help you become one. Suppose that you prove to your class whether or not flies carry germs on their bodies!

Suggested Experiment. — Secure two prepared Petri dishes, a glass slide, a cover glass, a dissecting needle, and a microscope. Catch an ordinary house fly and place it in one of the Petri dishes, covering the dish with its cover. Allow the fly to walk about several moments over the surface of the agar. Then allow it to escape and cover the dish. Keep the second dish covered. Why? Place the two dishes side by side in a dark warm place for several days. Watch for results. Can you tell after several days in which dish the fly was imprisoned? Explain. Remove by means of the needle a small portion of one of the dots or colonies from the contaminated Petri dish and mount it with a drop of water on a slide and cover with cover glass. Examine under the high power of the microscope. What do you see in the microscope field? What is the shape of the organisms observed (Fig. 316)?

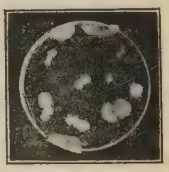


FIGURE 316. — FLIES AND BACTERIA.

A fly visited this Petri dish. Was the fly clean? Explain.

531. The House (Typhoid) Fly Guilty. — It is estimated that the number of bacteria on the feet of one fly averages around 1,500,000. In this number it is reasonable to suppose that some are disease germs. The fly is known to spread tuberculosis, bubonic plague, cholera (kŏl′ĕr-*a*), and other diseases. Most of the deaths of infants under one year of age, due to cholera infantum, are traced to the house fly.

Out of 5550 deaths due to diseases carried by insects during 1908 in New York City, it was estimated that 4272 were caused by the fly. Five thousand American soldiers died of typhoid fever during the Spanish-American war, largely due to the fly. The estimated financial loss to

the country from typhoid fever each year is $350,000,000. This also, we may say, is chiefly due to the fly.

532. Protection from Flies. — The killing of every stray fly found about the house in late fall and winter will prevent the growth of millions the following summer. The elimination of all possible breeding places, such as garbage, filth, and manure piles, is a sure method of getting rid of the fly. The constant sweeping of the streets prevents the accumulation of filth favorable to fly growth. Can you see how the development of the automobile may in time reduce the number of deaths from typhoid fever?

The frequent and thorough scattering of manure, the burying or burning of garbage or feeding it to swine will greatly reduce the swarms of flies about the average farm. Sunlight, intense heat, and air will effectually destroy most fly eggs and larvae. A screen should be fitted to every window and door in the house. To fail to do this may mean the loss of human lives. The last line of defense is fly poison. Since the favorite food of flies is bread and milk, this can be used as a bait. Add 2 tablespoonfuls of formaldehyde (fôr-măl′dē-hīd) to a pint of water and milk. Add a little sugar and some bread. As flies are thirsty in the morning they will soon find the bait, if it is exposed early. The dead bodies about the trap will prove the success of your experiment.

533. The Mosquito. — There are many varieties of mosquitoes, but only two forms are commonly found in temperate regions. One is called the *Culex* (kū′lĕks). A study of Key Picture 22 will give you its characteristics. The other form, known as the *Anopheles* (ȧ-nŏf′ē-lēz), is the dangerous form and can be distinguished by its striped legs. Its other characteristic is shown in Key Picture 22. What is it? Both forms breed only in the water. The female lays from 200 to 400 eggs at one time. Study the life history of the mosquito (Key Picture 22), and be able to explain it.

The possible offspring of a mosquito in one season is unbelievable by those who do not think about these

things. One adult may be represented by the figure 2 with 39 zeros following it. Fortunately, this is not actually the result, since there are hundreds of obstacles to the maturing of the eggs, one of these obstacles being man himself.

FIGURE 317. — MODEL OF THE MALARIA MOSQUITO.
Note the striped legs.

The life history of the malarial parasite itself is of no less importance than that of the mosquito. A careful study of the steps of the progress of this disease should be made in connection with Key Picture 22. Malaria is one of the most common and most dreaded diseases in the world to-day because of its effect upon one's ability to work.

534. Prevention and Control of Mosquitoes. — Never was the maxim that " An ounce of prevention is better than a pound of cure " better applied than in the control of mosquitoes. Since they breed only in stagnant water, swamps, and in receptacles such as rain barrels and tin cans, these are the places to destroy their eggs. The draining of the swamps, the overturning or removal of the cans, and the covering of the rain barrels with mosquito netting, will put an end to this menace. Examine any tin can containing water after a rain and see how many mosquito larvae or pupae you find there.

In case a swamp which cannot be drained is located near your home, the next best thing to do is to pour crude oil upon its surface at different points and let it spread.

Suggested Experiment. — The effect of this can be proved experimentally by taking a few of the larvae in your experiment and after placing them in a jar of water, pour over the surface of the water a little oil of any kind. Note the action of the larvae and

what finally happens to them. Can you explain this result? Here you see an effective attack upon the weakest link in the life history of the mosquito. It never fails to work. If you find mosquitoes thick about your home, there is a good reason for it. It is your business to find out the source of this invasion and stop it for your own protection against disease.

535. Fleas, Lice, and Bedbugs. — The presence of these insects in the home is generally considered as indicating uncleanly ways of living. They may be, however, and often are, picked up on the clothing while traveling or visiting. Yet again pet dogs and cats may bring them into the home. Their greatest menace is in their ability to carry disease. The dog and cat fleas are known to carry bubonic plague

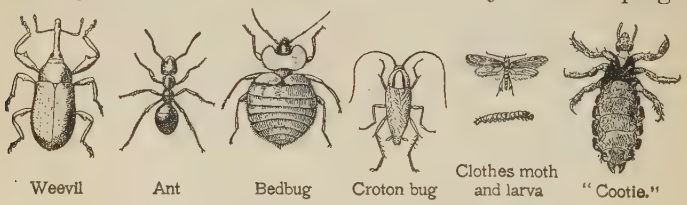


FIGURE 318. — SOME HOUSEHOLD PESTS.

How is each of these insects a pest in the home? How is each controlled?

germs. Such fleas are infected by biting rats which have the disease. They then communicate the disease by changing *hosts*, — going perhaps to a dog or cat and then to man. The easiest way to avoid fleas is to keep the beds of pet animals clean. The animals should be treated with good insect powders. All crevices about the house where these insects run should be thoroughly dusted with such a powder. "Nits" or head lice are often found in school children's hair and can be eliminated by a mild application of kerosene and vinegar.

To exterminate the bedbug is easy by *thorough* cleaning of bed, floor, and wall crevices, and the use of reliable insecticides which are obtainable at any drug store (Fig. 318).

536. Food and Clothes Eating Insects. — The cockroach, the "croton bug," ants, and weevils are all nuisances, though

not to be especially feared as disease carriers. Food should not be left about where they can reach it, food scraps and garbage should be disposed of at once, and open plumbing should always be used. Borax mixed with sugar should be scattered about where they run. No large quantity of dried peas or beans should be kept on hand. This attracts the weevils.

The larvae of the clothes moth and carpet beetles destroy woolen clothing, furs, rugs, and carpets amounting to millions of dollars every year in the United States alone. The adult moths fly about the house in early spring. Not one should be allowed to escape. Explain. Winter clothing and rugs before being stored for the summer should be carefully brushed and aired, then put in medicated bags and sealed. Explain. Suppose that the clothes are put away with a clothes moth or larva in them? Explain the result (Fig. 318).

537. The National Pest, the Rat. — This is the worst mammal known to man. It destroys over $100,000,000 worth of grain in the United States every year. It carries disease, since it prefers the sewer or drain pipe for its home. It is responsible for the bubonic plague, which has killed 25,000,000 people in Europe and 5,000,000 people in India alone. Rats destroy food, clothing, paper, books, plaster, woodwork, — almost everything about the home. Poisoning rats is dangerous. Why? Trapping them by concerted action on the part of a whole village or city is the only remedy. Keeping all food away from their reach is the next best thing. It is a fact that bacteria, insects, rats, and man have formed a biological relation which has cost the world hundreds of millions of lives and untold ages of misery and pain. Modern biology has discovered this relation within recent years.

2. How the Body Defends Itself against Disease

538. External Dangers and Internal Protection.—Through a long period of time the body has acquired power to set up a system of defense or protection against the invasion of

germs from no matter what source. This power, when properly aided by artificial and natural means, makes the body strong to resist disease. Like an army, the body has several lines of defense. What is the nature of these defenses?

539. The Body's First Line of Defense. — The human skin is a very tough covering made up of several layers of tissue; liquids, most poisons, and bacteria cannot enter as long as its surface is not broken. It is the natural defense of the body against all outside injuries. If it is cut or badly bruised, blood escapes, indicating the rupture of capillaries, and your first line of defense has broken down. Explain. To prevent further trouble, wash out with clean cold or warm water any dirt that may have entered the bruise. Then a 5% solution of carbolic acid or the usual tincture of iodine should be at once applied.

540. The Body's Second Line of Defense. — The white or colorless corpuscles move about the body by flowing movements, even progressing against the blood stream,

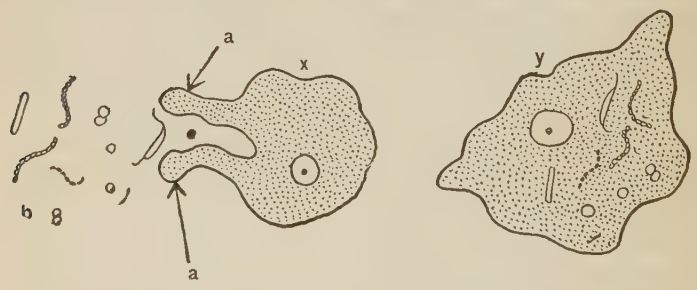


FIGURE 319. — WHITE CORPUSCLES AND BACTERIA.

A white corpuscle (**x**) engulfing bacteria (**b**) with its false feet or pseudopods (**a**, **a**) which flow about the germs and take them into its body (**y**) where they are soon destroyed by being digested.

creeping out of the capillaries, and going about between the cells (Fig. 319). Congregating in large numbers where the bacteria are numerous, they devour them, aided by substances in the blood which (1) cause the bacteria to stick together and (2) make them attractive to the white corpuscles.

Aided by *antitoxins* (ăn′tĭ-tŏk′sĭnz), which the cells make and pour into the blood stream when he has a disease, the average person is immune (ĭ-mūn′) to that disease when the bacteria get into the blood a second time. He is actually able to ward off disease through this immunity. Such immunity is known as *natural* and may be characteristic of a whole race for any particular disease (Key Picture 23).

541. The Body's Third Line of Defense. — Natural immunity protects us from many diseases, but there are some from which most of us are not immune, such as diphtheria (dĭf-thē′rĭ-*a*), smallpox, and typhoid fever. Most of us have been *vaccinated* (văk′sĭ-nāt′ĕd). Do you really know what this means? In both smallpox and diphtheria immunity is acquired by methods shown in Key Picture 23. Study these methods and explain them to the class.

542. Artificial Reinforcements which Aid the Body to Ward Off Disease. — Cleanliness is the greatest aid to the body in preventing disease. To keep clean requires much sunshine, much air, and a generous supply of soap and water together with the proper use of disinfectants. Carbolic acid, lysol, formaldehyde, iodine, bichloride of mercury, and chloride of lime are all deadly poisonous to both man and bacteria. These substances in solution are often used in cleaning or scrubbing woodwork and floors. They are poured occasionally into washbowls, sinks, and toilets to prevent the growth of bacteria. All such poisons should be kept in a safe place, well out of the reach of children, and should be so plainly labeled that no one can by any manner of means use them by mistake for medicine. Many lives have been lost through failure to take such precautions.

543. What You Can Do to Help the Body Resist Disease. — Aids to artificial methods of combating disease are happily many and inexpensive. They are repeated here for emphasis.

1. *Fresh Air.* Full and complete ventilation of living and sleeping rooms, the wearing of porous clothing, plenty of

outdoor exercise, setting-up exercises before an open window, and deep breathing will mean death to bacteria and disease.

2. *Food.* You ought to eat just the right amount of food as determined by your age, occupation, and the season. The kinds of food should also be carefully considered.

3. *Teeth.* Failure to keep the teeth clean means bacterial decay, the entrance of protozoans, and the formation

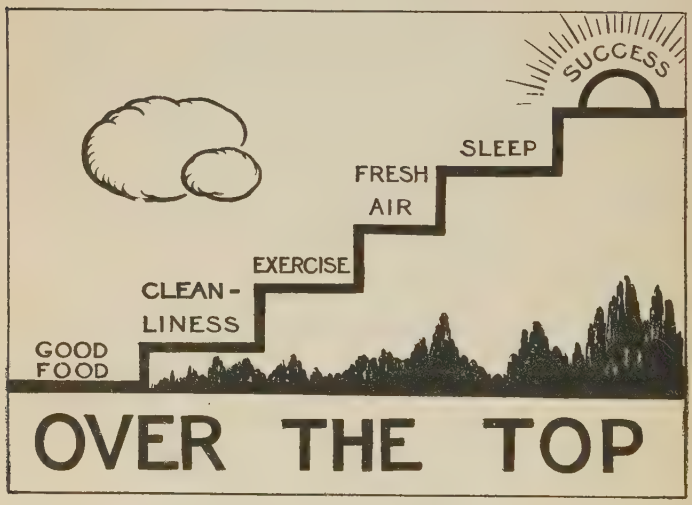


FIGURE 320. — STEPS TO SUCCESS.

How do these steps depend on one another? Explain how each is necessary for success.

of toxins which poison the whole body. Eye strain, pains in the back, rheumatism, heart trouble, and nervous diseases are all often due to poor teeth. Without good teeth proper chewing of food is impossible. Constipation and the loss of efficiency follow.

4. *Water.* Water is cheap. It is the natural flusher of the body. It prevents constipation. It aids in food absorption. It prevents decay of food in the intestines. You should drink at least six glasses of water each day.

5. *Exercise.* Any work involving use of the muscles is good exercise. Playing ball, running errands, rowing, and tennis are all good ways to keep the body in health. They help the whole body to throw off wastes and obtain plenty of air, and make it more active. But remember! Over-exercise is not good for the growing boy or girl.

6. *Sleep.* After exercise comes fatigue. This should never approach exhaustion. Such a condition is dangerous and destroys the value of all exercise. To eliminate fatigue poisons requires rest. Every boy and girl should sleep at least eight hours every night (Fig. 320).

3. The Origin, Importance, and Use of Clothing

544. Clothes and Health. — Clothing is a hygienic necessity. But it must be porous to be hygienic. We may say, then, that clothing has two important uses. (1) To protect the body from mechanical injury and (2) to regulate the body temperature so as to prevent sudden chilling of the body surface which would often occur when going from a warm room into zero weather.

545. Sources of Clothing. — A little thought will show you that all your clothes are derived from plants or animals.

(*a*) *Wool.* This is one of the oldest sources of clothing in the world. It is taken from sheep and has been used since men first began to herd animals. It was the basis of one of the first industries known.

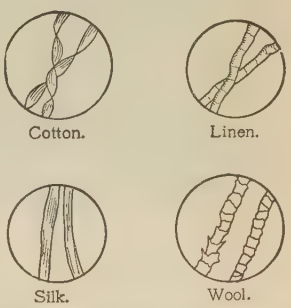


Figure 321. — Cloth Fibers (Much Enlarged).

Why is wool cloth rougher than cotton, linen, or silk cloth?

A characteristic of woolen threads is their minute projecting scales. These scales hold the threads together, give them firmness, a rough texture, and good wearing qualities (Fig. 321). Wool holds large quantities of air between the

fibers, allowing the absorption of moisture and the retention of heat by the body. It is this property which makes woolens so warm in winter. One never feels clammy or chilled in them after violent exercise because they absorb the perspiration from the body surface.

(*b*) *Cotton.* Since cotton threads are much smaller than woolen threads and also lack the scaly projections, cotton

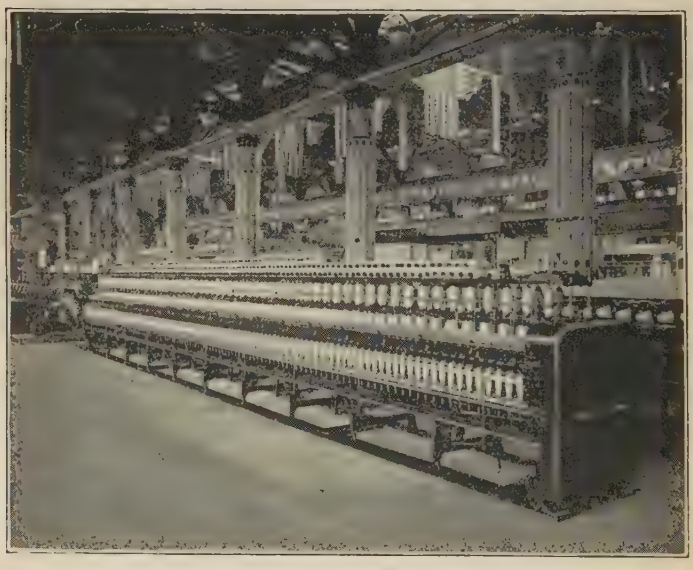


FIGURE 322.—A SOUTHERN COTTON FACTORY.
Here cotton is spun into thread and the thread woven into cloth.

cloth is always more closely woven; the air spaces between the threads are smaller and the cloth is thinner. Thus, since little air is held in the cloth, it allows heat to pass readily through it. It is thus a poor winter covering but a good summer covering for the body (Figs. 321 and 322).

(*c*) *Linen.* Linen thread and cloth are made from the macerated (softened) fibers of the stem of the flax plant which is grown in large quantities in Belgium and France. Linen

cloth is always stiffer than cotton cloth and takes starch more readily.

(*d*) *Silk.* This wonderful substance comes from the cocoons of the silk moth larva, which spins it during its change from the caterpillar to the adult flying insect. Dipped in boiling water which kills the inclosed organism, the silken threads are unrolled and woven into silk cloth. It takes 90,000 silk

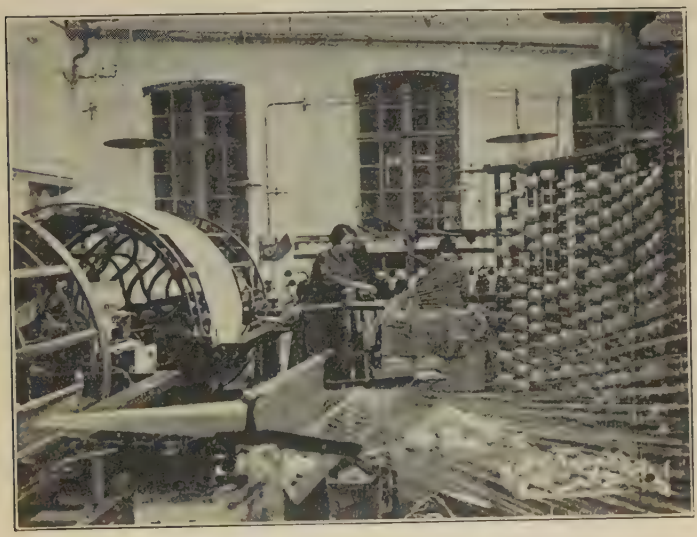


FIGURE 323. — A SILK MILL.

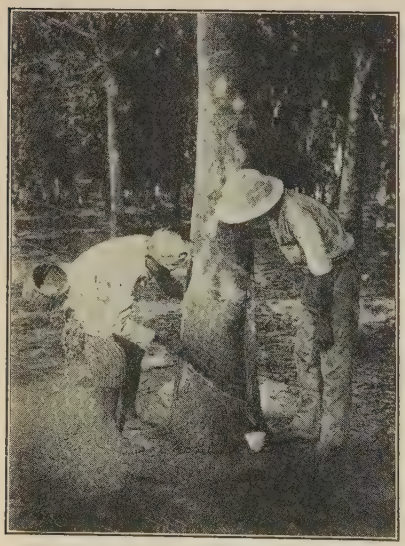
Here silk threads are spun and woven into delicate fabrics.

cocoons to make one silk dress. Most silk is produced in Japan and woven into cloth in the United States (Fig. 323).

(*e*) *Rubber.* Our rubbers and raincoats come from the latex (lā'tĕks) or milk of the India rubber tree largely grown in Brazil and known as Para rubber. Study Figure 324 and see how the milk is obtained. Wooden paddles are dipped in this latex or milk and dried over a smoky fire. Layer after layer is formed on the paddle. Then it is stripped off and sold as raw rubber. It is then mixed with sulphur to pre-

vent rotting, run into molds, and made into gloves, rubbers, and many other familiar articles.

(*f*) *Furs.* In the skins of fur-bearing animals no removal of the hair takes place. After being dried or cured the skin side is covered with cloth or other material, leaving the fur exposed. The great warmth of furs is due to the fine hairs which hold great quantities of air between them. It is estimated that the fur of a cat consists of 92% air and only 8% real hair. Furs are the warmest coverings that can be worn in extremely cold weather because they are great non-conductors of heat. Explain.



U. S. Rubber Co.

FIGURE 324. — TAPPING A RUBBER TREE.

Raw rubber is a sap, which hardens and is heated to make it tough and durable. Name all the rubber articles you can think of.

546. How the Skin Regulates the Body Heat. — If you were to take your temperature with a clinical thermometer on the coldest day in winter and again on the hottest day in summer, both readings would show 98.6° F., provided you were in good health. How does this happen? The blood in the skin gives off heat, and the skin regulates the body temperature by controlling the amount of blood in the skin. You feel cold or warm according to the amount of blood in the skin, but the internal temperature of the body remains the same.

The skin is richly supplied with sweat glands (Fig. 325), which open upon its surface. During exercise, excess body wastes in the form of water, uric acid, oil, and salt are carried

by the blood to these glands and are excreted by them out upon the surface of the skin. Heat goes with these wastes, which are evaporated from the surface of the body, and the body is cooled. On a cold day, the blood keeps away from the skin surface, the pores are closed, and this heat tends to stay in the body where needed. Why do you

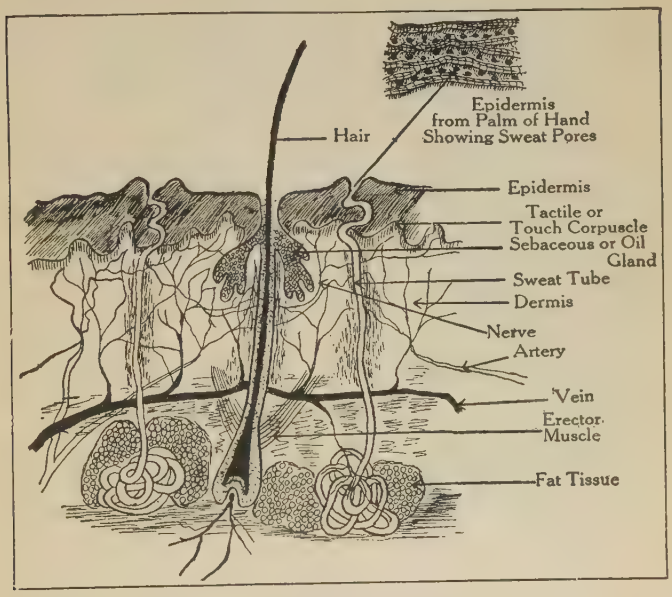


FIGURE 325. — SECTION THROUGH THE SKIN.

Study each labeled part. Try to determine the function of each part.

feel uncomfortable on a warm "muggy" day? Why do you feel comfortable on a clear, cold day?

547. Clothes and Body Protection. — Dark woolens should be worn in winter because much radiation of heat then takes place from the body and you want to keep the heat in. Furs are valuable, then, for the same reason. Explain. However, in summer, white cotton and linen are best used because in that season you desire to lose heat. On the other

hand, excessive exertions in summer may result in a cold due to the too rapid loss of heat after the exercise and the inability of cotton or linen to stop this loss. Explain. In such cases a warm sweater made of wool is best to use as a temporary body covering until the danger point is past and the clothing is changed. This is why athletes always don warm wrappings after a race. In cool summer evenings it is well to wear a sweater. Explain. To allow the loss of body heat, silk clothing is commonly worn in summer. Cloth or canvas shoes are cooler than leather shoes. In fact, leather is a poor conductor of heat at all times. It keeps our feet warm in winter, but it lets little body heat out, often causing sweating and sore feet. Leather shoes should actually have air holes in them for ventilation, but at the same time the danger of wet feet should be guarded against. Rubbers keep in most of the heat and so should never be worn except when actually needed for protection against cold or water. In all your uses of clothes you should keep in mind how they can best be worn to take account of (1) sudden changes in weather; (2) change of seasons; (3) changes in temperature.

548. Underclothing and the Skin. — In winter you should wear underclothing which is a relatively poor conductor of heat. A mixture of wool and cotton is best because the wool absorbs the moisture from the body, thus preventing chills, and the cotton allows excess heat to leave the body. Most colds are due to the use of too heavy or too thin underwear. Indoors, many people are constantly perspiring. When they step out in the cold the skin pores close suddenly, congestion takes place, and a cold results. The solution is the use of relatively light underwear of great porosity and the wearing of heavy outer garments which can be put on or removed with ease.

4. Care of the Skin and Clothing

549. Care of the Skin; Bathing. — Some of the skin waste is gradually worked into the clothes, and some remains upon

the surface of the skin. This waste must be removed if one is to be presentable and healthy. The frequent bathing of the body and thorough washing of all underwear is the right solution of this problem. Bathing keeps the pores of the skin open and clean. In summer, baths should be very frequent; in winter, at least once each week. Explain. A cold shower hardens the skin, tones up the whole body, hastens circulation, and cleans the skin. A thorough rubbing down after the shower makes for greater vigor and health. But if a chill always follows a rub down, cold baths are not good for you. Experience will give you the final word in this matter. Change slowly from warm to cold water and the average body will become accustomed to this change and will welcome the stimulus. Cold baths should be taken in the morning, never at night. Warm baths should never be taken in the morning. Going out with open pores may mean sickness. Explain. It must be added that a thorough use of a good soap is always to be recommended in bathing because this treatment is necessary to insure the complete removal of all body wastes and odors.

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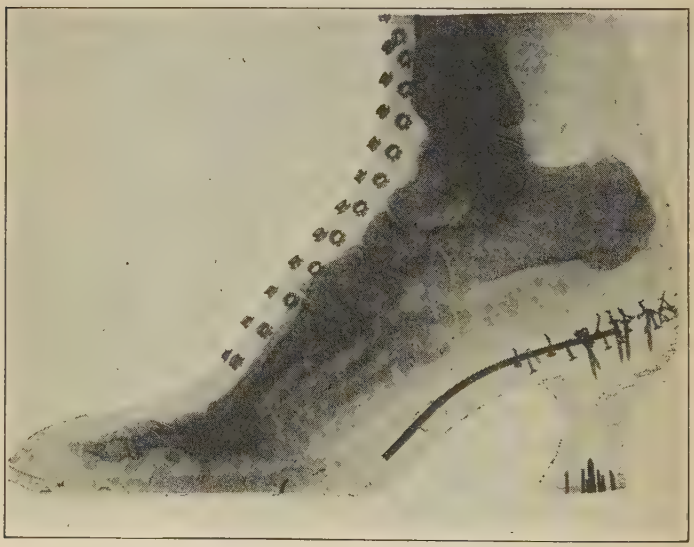
FIGURE 326A. — A WRONG-TOED SHOE.

1, enlarged joint and toe bent out of line. **2**, where toe should be. **3**, the end of the big toe pushed over the next toe.

550. Care of Feet. — The feet should always be kept dry when in shoes. If they become wet, they should never be allowed to remain so. Rubbers will prevent colds, because they keep out the wet and prevent the loss of heat from the body. Foot folly is one of the greatest disturbers of our com-

fort to-day. Men and women, boys and girls should know the necessity and advantage of sensible shoes and comfortable feet (Figs. 326a and 326b).

551. Sixteen Health Rules You Should Keep. — In the book entitled "How to Live" by Professor Irving Fisher of Yale University, and Dr. E. L. Fisk, the statement is made that 600,000 deaths in the United States might be prevented



Dr. W. A. De Lacey.

FIGURE 326B. — A WRONG-HEELED SHOE.

This girl is straining her foot. Why? This means deformed leg muscles and feet. Avoid the extremely high heel.

each year if our present knowledge of hygiene were actually applied in daily life. It is also stated that one half of the 3,000,000 people who are constantly ill in this country might be well if hygiene were practiced, and that the financial loss from loss of earnings through sickness is $1,500,000,000 each year. Finally, the authors tell us that fifteen years would be added to the average length of life if all obeyed the rules

of hygiene which have already been given you at the end of Chapter XIX.

Hygienic living costs nothing. Fresh air is free, water is cheap, exercise is free, soap is cheap. Review and memorize the rules on page 580. Try to follow them in your daily life.

552. Body Protection and Work. — No engineer would keep his position long who did not give proper care and protection to his engine. Your ability to make the human engine do its appointed daily tasks depends upon your knowledge of hygienic rules and your ability to use your will power to follow these rules day by day. You cannot become an athlete in a minute nor can the body be destroyed in a minute by neglecting proper habits of living. Progress or destruction are both accumulative over the years, but the results are as certain as anything can be. To be happy and successful in life depends upon what you are doing with your body.

Boys and girls who keep the body clean in every way and respect it are confident and capable. Since they are honest with themselves, they are not ashamed to look anyone in the eye. This self-respect which comes from thorough cleanliness and body protection makes for happiness and success. Such success is yours for the asking. What will you do about it?

SUMMARY

Since all living things must have food, there must be a continual conflict between man and other organisms. Among the latter are the *house fly*, *mosquito*, *flea*, *louse*, *bedbug*, — all of which may *bite* man, perhaps injecting into his blood *disease germs*, or may *pollute* the *food* which he eats. Again, certain house insects (*cockroaches*, *ants*), *rats*, and *mice* are disagreeable because of their filthiness.

To control these pests we must know their complete life history and habits in order to attack them at their weakest point. Destruction of the *larval forms* of the insects by *oils*, the elimination of wastes where they breed, and the use of *powerful poisons* are found to be most effective.

The *human skin* is the *natural defense* against disease. If it is broken, and disease germs enter the blood, the *white corpuscles* sometimes destroy these germs. Substances called *antitoxins*, produced by

the blood, check the effects of the bacterial poisons (*toxins*). In some cases, *immunity* can be gained only by *artificial* means. *Vaccines*, when injected into the blood, give one a mild form of the disease, thus causing the production of *antitoxins* to check the toxins of smallpox, etc., should they enter the body.

Disinfectants prevent the growth of germs outside of the body. *Antiseptics* are applied to the body itself. The greatest aids to good health, however, are a *clean body*, *clean clothes*, *clean food*, *clean homes*, and *clean places of social meeting*.

Clothing made from *wool*, *silk*, *cotton*, *leather*, *furs*, *rubber*, etc., protects the body from the *weather* and *injury*. The skin and clothing regulate body heat. It is important to know what clothing to wear and when to wear it.

Bathing keeps the body free from *odors*, *increases circulation*, *tones up* the body, and helps to protect it from disease. Bathing must be adjusted to the age, to the seasons, and to time of day.

The feet need care through proper *sized* and *shaped shoes*, *bathing* of the feet, etc. Finally, all clothing should be kept in a *clean* and *whole* condition. This develops self-respect, insuring happiness and efficiency.

Remember that :

1. Certain insects, in destroying food and biting man, infect both with disease germs.
2. The body is naturally protected against disease germs.
3. Artificial reinforcements must often be used to aid the body in warding off disease.
4. Proper habits of living are the best guarantee against disease.
5. Proper clothing, proper bathing, and proper care of the feet are tremendous aids in insuring body efficiency and comfort.

THOUGHT QUESTIONS

1. What disease caused the greatest number of deaths in your town or city during the past year? Can you account for this?
2. How can you prevent the breeding of mosquitoes near your home?
3. Why is expectoration upon street cars, public buildings, and on sidewalks prohibited in most towns and cities?
4. What is the advantage of laws preventing the use of public drinking cups?
5. What is meant by a disease carrier? Give examples.
6. Give several reasons why meat and provisions should be kept under glass in markets and food stores.

7. Someone has said that the total weight of all the microorganisms in the world is greater than the total weight of the animals of the world. Discuss this statement.

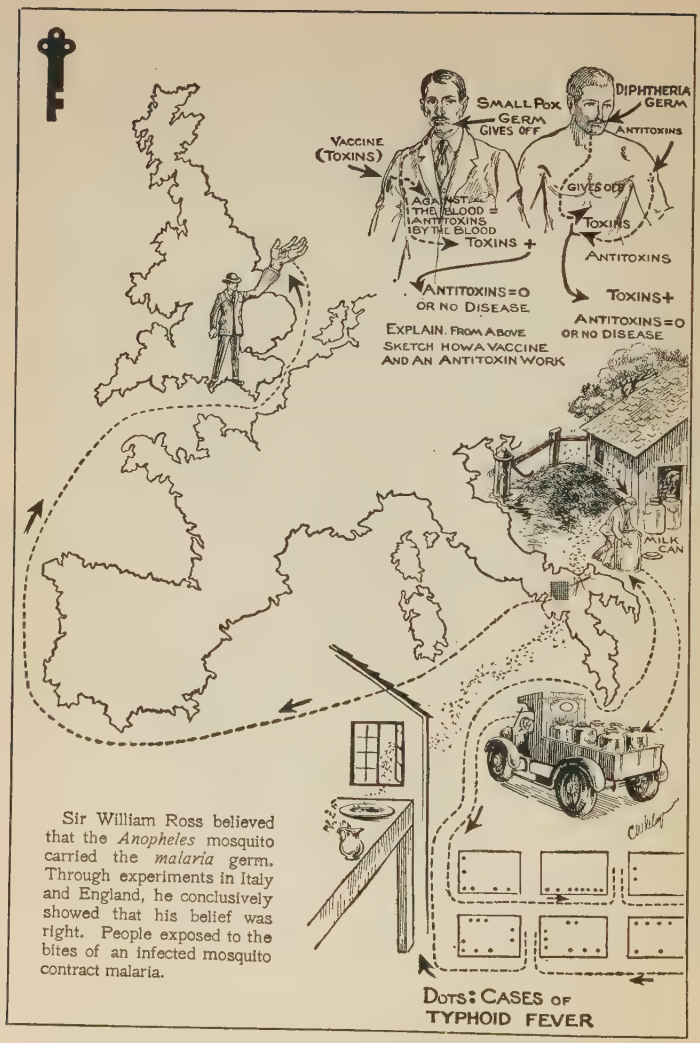
8. The average length of life of man in the world is increasing every year. Why? Explain.

9. Men have exterminated the passenger pigeon and other animals, yet not one species of bacteria has been exterminated by man. Explain.

10. What is the great advantage of keeping food in sealed containers?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Basset. The Story of Leather. Penn Publishing Co.
Basset. The Story of Silk. Penn Publishing Co.
Basset. The Story of Wool. Penn Publishing Co.
Broadhurst. How We Resist Disease. J. B. Lippincott Co.
Chamberlain. How We Are Clothed. The Macmillan Co.
Cruess. Food and Farm Food Preservation. The Macmillan Co.
Evans. How to Keep Well. Roebuck.
Harding. Boots and Shoes. Isaac Pitman and Sons.
Hartman and Bibb. The Human Body and Its Enemies. World Book Co.
Herrick. Insects Injurious to the Household. The Macmillan Co.
Moore. Linen: From the Field to the Finished Product. Isaac Pitman and Sons.
Turner. The Nature of Fabrics. D. Appleton and Co.
Turpin. Cotton. American Book Co.
Stevens and Beadle. Rubber. Isaac Pitman and Sons.
Williams. Healthful Living. The Macmillan Co.


SMALL POX GERM GIVES OFF
DIPHTHERIA GERM
VACCINE (TOXINS)
ANTITOXINS
GIVES OFF
AGAINST THE BLOOD = ANTITOXINS BY THE BLOOD
TOXINS +
TOXINS
ANTITOXINS
ANTITOXINS=0 OR NO DISEASE
TOXINS+
ANTITOXINS=0 OR NO DISEASE
EXPLAIN. FROM ABOVE SKETCH HOW A VACCINE AND AN ANTITOXIN WORK
MILK CAN
Sir William Ross believed that the *Anopheles* mosquito carried the *malaria* germ. Through experiments in Italy and England, he conclusively showed that his belief was right. People exposed to the bites of an infected mosquito contract malaria.
DOTS: CASES OF TYPHOID FEVER

KEY PICTURE 23. — HOW DISEASE IS SPREAD AND PREVENTED.

Tell the story of how smallpox and diphtheria are prevented. Tell the story of the milk-man and his route.

CHAPTER XXIII

THE WORK OF PROTECTING THE COMMUNITY FROM THE DANGERS OF ITS ENVIRONMENT

With health all taste of pleasure flies.
Nor love, nor honor, wealth nor power
Can give the heart a cheerful hour
When health is lost. Be timely wise.

—Gay

Almost every discovery in science, almost every advance in engineering has contributed some fact or condition of practical importance to general hygiene.—Wm. T. Sedgwick.

Do you live in a healthy community? What makes it so? Does this help your town? How? Think of some of the dangers which come because you live with a large number of other people in a town or city. How must a community protect its food and water supplies? Why must it protect them? Did you ever hear of an epidemic in a city? What is an epidemic? Give several ways in which epidemics are prevented or stopped. Did you ever hear of the Great White Plague? What is it? How can this be checked? How prevented? How cured? Why are insects of great danger to your town? Why must you have good health officials in a town or city? How can you be a good citizen in your town as far as the health of your town is concerned? A close study of this chapter will help you become a better citizen.

Some Practical Questions :

1. Why are epidemics less frequent and less to be feared than in the days of our forefathers?

2. Why is it right that you should obey the orders of health officers at all times and especially during an epidemic?

3. Why are epidemics rare in the country districts?

4. Why is machine-made ice required by health officials even in cities where natural ice is plentiful?

5. Inspect your own home and indicate the things or conditions which might contribute to the beginning of an epidemic in your neighborhood.

FIGURE 327. — A MODEL COW STABLE.

From this stable milk is sent to New York City. What makes it a good stable?

Home Problem. — Make a careful survey of your home for one week and discover, if possible, any way in which you or the members of your family are doing things which might in any way cause sickness in the community. If you find such negligence, try to explain the situation to your parents and have them coöperate with you in stopping it. Report your results to your teacher.

Field Problem. — Make a study and survey of your entire block. Note if any families are neglecting to do the necessary things to keep the community from sickness. Kindly suggest to any family showing neglect that it would be nice if they would keep in mind the rest of the block *or* if you had rather do so, consult your street-

cleaning inspector and determine by his help whether or not you should notify the health commissioner of the conditions you note.

Report the results of your work to the class.

1. Dangers in and Protection of the Food Supply

553. The Health of the Community. — To-day a community is judged by its health record, because the health of any community is dependent upon its cleanliness. Again its cleanliness is dependent upon the efficiency of the community officials, especially the health officers. Finally, the

Figure 328A. — A Dangerous Food Store.

Is the sign a true one? List all the bad conditions here. Explain them. Note the cat. Refuse to trade at such stores.

efficiency of the health officers is dependent upon the kind of people that live in the community. Thus, we see that the health of any community largely depends upon the kind of people that live in it. Explain.

554. Agencies for Protecting the Health of the Community. — City and large town governments are generally

divided into bureaus or departments, each one having its special work to do. The department of street cleaning cares for the streets and carries away garbage, ashes, and rubbish. The department of health inspects foods, milk, and water; enforces the sanitary code, stops nuisances, controls contagious diseases and quarantines; and examines patients too poor to pay for medical attendance. But in none of its

FIGURE 328B. — A SANITARY MARKET.

Why is this store an improvement over the one in Figure 328a? Explain fully.

various duties are its labors so important and yet so little noticed by the community as in the control of foods.

555. Protection of Our Foods. — Most cities now require the pasteurization of milk which is to be sold within their limits. Why? They also inspect this most important food. Why? Most cities insist that food stores shall be clean and sanitary. Why? All perishable foods and foods not in containers must be kept under glass, protected from han-

dling by customers, and well screened.[1] Explain. Foods must not be displayed on the sidewalk or floor. Why? Again, our meats are inspected by United States officials who are paid to see to it that all animals killed for meat are in good condition when killed.

FIGURE 329. — FEDERAL INSPECTION OF MEAT.

This is a cold storage plant. The meats are being inspected, however. Why? Of what value is this to you?

Fish, fowl, and like foods are examined in cold storage (Fig. 329) and even in the market. If found unfit for use, they are condemned and destroyed. Thousands of pounds of groceries and canned goods have been destroyed because they were unfit for use.

[1] In actual tests 15 bacteria were found on culture dishes exposed 10 minutes in a supposedly clean glass case, while one dish exposed on an open counter 10 minutes collected 800 bacteria. On the sidewalk 10,000 bacteria were collected in 10 minutes and in a loaf of wrapped bread 7500 bacteria were found.

FIGURE 330. — A FILTHY BAKERY.

This shop is in a cellar. Name the wrong conditions here. Choose your bakery with care.

556. Food Adulteration. — We have already mentioned the importance of restricting and controlling food adulterations.[1]

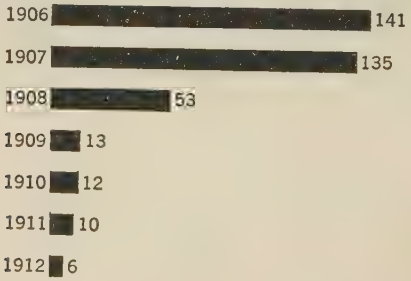


FIGURE 331. — EFFECT OF THE PURIFICATION OF WATER SUPPLY.

How the typhoid fever death rate was reduced in Pittsburgh, Pa., through filtration.

[1] In many towns and cities merchants selling only pure foods are placed on "white lists" which are published in the newspapers. Westfield, Mass., publishes a pure food booklet which may be had for the asking.

That the government uses the great power given it to protect the people is shown by the following:

12,000 PROSECUTED UNDER PURE FOOD LAWS

Adulteration and Misbranding Being Gradually Corrected by Federal Seizures.

August 25, 1924. Great progress is being made by the government in the seizure and prosecutions of misbranders and adulterators of foods. There have been 600 egg seizures and prosecutions based upon spoiled eggs. 100 cases of misbranded flour have been completed. Dairy products and other similar products comprised over 1000 of the 12,000 court actions involved. In some cases three kinds of adulteration were found in one batch of milk — skimmed, watered, and spoiled.

Other recent seizures under the Pure Foods and Drug Act include flavoring extracts, vinegar, oysters, nuts, oranges, canned fruits and vegetables, evaporated apples, beverages, candy, coffee, lard, meat, jams, jellies, syrups, stock feed and grains.

—*New York Times.*

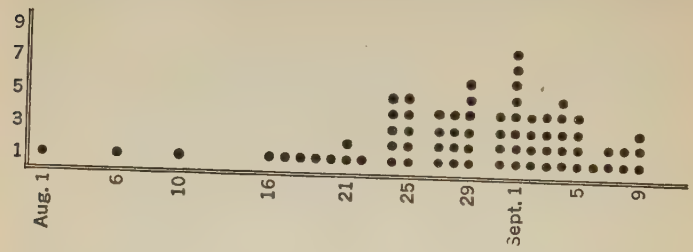
557. Control of Water Supply. — This topic was fully treated in Chapters VI and VII. You are advised to review it thoroughly (also your notes written in your Science Discovery Book) as an aid to a full understanding of the importance of the protection of the community from disease.

2. Dangers in and Control of Epidemics

558. Epidemic Diseases. — In the North Temperate Zone it has been found that the following diseases are epidemic: Typhoid fever, diphtheria, scarlet fever, measles, mumps, whooping cough, smallpox, meningitis (mĕn'ĭn-jī'tĭs), infantile paralysis, and influenza. By being carried from one person to another by contact, by being scattered through air, dust, water, and milk or other foods, the germs of such diseases may infect a whole community (Fig. 332a).

559. Control of Epidemics by Quarantining. — All epidemics need immediate and rigid control. Children are

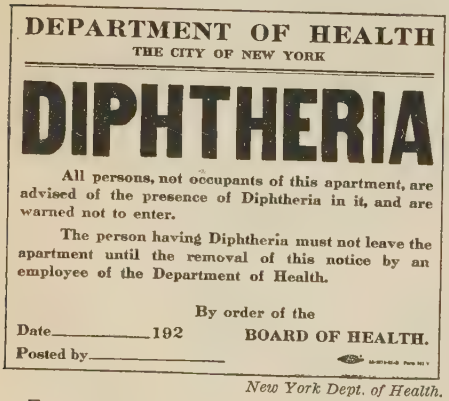
often sent to school after being exposed to contagious diseases, and during the incubation period of the disease may cause



New York Dept. of Health.

FIGURE 332A. — HOW TYPHOID FEVER WAS SPREAD BY MILK.
On August 1 the first case developed. Note August 29 and September 1. How did all these cases arise? Tell the story.

an epidemic. This is extremely dangerous. Explain. One of the methods used to prevent the spread of epidemics is that of *quarantine* (Fig. 332b). In every well-governed city *all cases of contagious diseases must be reported at once to the authorities.* They immediately placard the home where the disease occurs, warning people to keep away and prohibiting the going out of any well members of the family or the moving of the person having the disease. In New York Harbor, the Federal Government keeps a quarantine station at Hoffman's Island in the Narrows and the hospital at Ellis Island takes care of all diseases brought in by immigrants.


DEPARTMENT OF HEALTH
THE CITY OF NEW YORK

DIPHTHERIA

All persons, not occupants of this apartment, are advised of the presence of Diphtheria in it, and are warned not to enter.

The person having Diphtheria must not leave the apartment until the removal of this notice by an employee of the Department of Health.

By order of the
BOARD OF HEALTH.

Date_____192
Posted by_____

New York Dept. of Health.

FIGURE 332B. — A QUARANTINE PLACARD.
What is the use of this card? What does it do for the public?

560. Prevention of Epidemics by Use of Disinfectants. — The use of chemicals in drinking water is essential to the proper care of the water supply. Again, care must be taken thoroughly to cleanse a home after the quarantine has been lifted from it. The burning of sulphur or formaldehyde was formerly recommended for this purpose in New York City, but now soap and water are the only cleansers required.

561. Vaccination. — Perhaps the greatest modern aid in the prevention of epidemics is vaccination. This method was first discovered by Dr. Edward Jenner in 1796, in connection with the disease smallpox. The method of action of the virus (poison) is simple. The virus which contains the weakened bodies of bacteria and their poisons is put into the blood of a person who has never had smallpox. The blood at once begins to build up a substance in itself to counteract these toxins or poisons. These new substances are called antitoxins. The person vaccinated has a mild form of cowpox, gets over it, and the antitoxins are left in his blood for an indefinite period. If the real smallpox germs should later happen to enter his body, the antitoxins are there ready to combat them or neutralize them and the person suffers no harm, in short, does not "catch" the disease (Key Picture 23).

562. Effect of Vaccination upon the Death Rate. — In Boston in the year 1721 more than half the people in the city had smallpox and nearly 10% died of it. It has been estimated that more than 60,000,000 people died of the disease in Europe from 1700 to 1800. Rarely does an outbreak of the disease now occur in the United States or even in Western Europe. In New York City, with a population of 6,000,000, there is now one death in six years from this disease.

563. Antitoxins. — In 1890 Dr. von Behring (fŏn bā′rĭng), a German bacteriologist, discovered an antitoxin which, when injected into the body, was at once circulated by the blood and almost immediately began to neutralize or stop the effects of the toxins which cause diphtheria.

When a person is suspected of having diphtheria, a culture is taken from his throat, sent to the board of health, and examined. If the report is positive, a bottle of serum or antitoxin is at once procured by the attending physician and injected into the blood of the patient by means of a hypodermic needle. Most physicians do not wait for the report but inoculate at once. Why?

564. Effect of Antitoxin upon the Death Rate. — The effect of diphtheria antitoxin upon the death rate was immediate as soon as it began to be used. Formerly, in New York City, 40% of all persons contracting the disease had died, but when this preventive was used, less than 8% died. To-day but one person in 100,000 in New York City dies of the disease.[1] The value of early treatment is well shown in Figure 333.

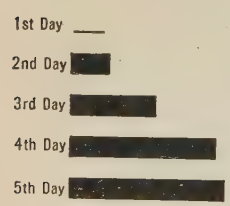
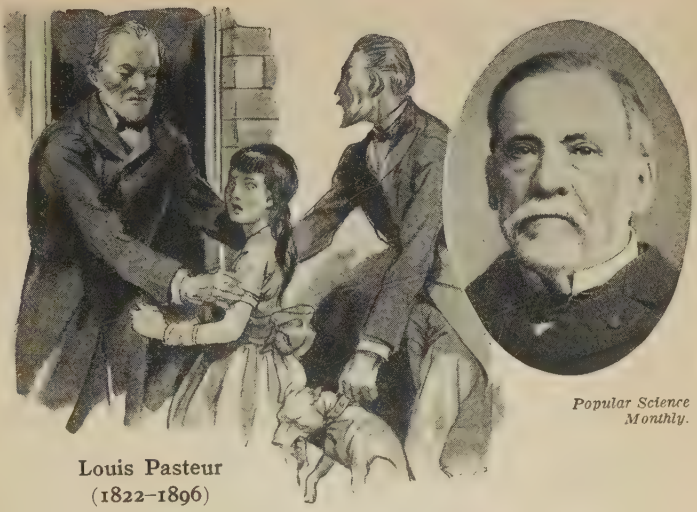


FIGURE 333. — HOW THE DIPHTHERIA ANTITOXIN WORKS.

Study this graph and explain the story it tells.

565. Hydrophobia Virus. — Louis Pasteur experimented for many years upon an antitoxin for the terrible disease called hydrophobia (hī′drŏ-fō′bĭ-*à*), resulting from the bite of a mad dog. Finally in 1885 he announced a specific treatment for it. Begged to try it upon a child who had been bitten by a dog, he finally consented and injected into the child several doses at stated intervals. The child did not develop the disease. Subsequent tests showed that the

[1] Experiments have shown that when the body is injected with the toxins of certain diseases, there will develop evidence as to whether the body is able to ward off certain diseases. Four of such tests are widely used. (1) The *Schick* test tells whether one is immune or can contract diphtheria. (2) The *Widal* test indicates whether a person has or has had typhoid fever. (3) The *tuberculin* test shows whether a person has or has had tuberculosis. (4) The *Dick* test shows whether one is susceptible to scarlet fever.



Popular Science Monthly.

Louis Pasteur
(1822–1896)

Born in a little village in France on December 27, 1822, he received from his parents the hereditary qualities and training which fitted him to become the greatest scientist of his age. He possessed an untiring curiosity, a persevering mind, a high regard for scientific truth, a firm belief in God, and a great desire to serve mankind. A learned physiologist, he also became a great teacher of geology and physics, with a genius for making difficult problems so clear and simple that the average person could understand them.

Working in the field of biology he demonstrated that life can come only from life; that most diseases are caused by toxins (poisons) given off by bacteria; that fermentation and putrefaction are the results of life processes; and that heat will destroy germ life in food without destroying the value of the food. He discovered cures for the silkworm disease, cattle fever, and hen cholera. He improved methods of vaccination and discovered an antitoxin for the prevention of hydrophobia. He placed in our hands the means of combating most of the dread diseases of to-day. He made milk safe for infants through pasteurization.

Though he was denounced on every hand because of his novel ideas, he persisted in demonstrating his theories and proving their correctness. Finally his gentle but confident manner convinced the world that he had something worth while for it and it was glad to pay him homage.

France holds Pasteur in veneration as the greatest man whom she has ever produced. His discoveries brought untold relief from suffering to mankind. His wonderful service to men merits their eternal gratitude.

virus can check most cases of hydrophobia and to-day the Pasteur treatment is a common one, given at Pasteur Institutes the world over.

566. Typhoid Vaccines. — Recent discoveries of Professor Wright in England led to the use of a vaccine for preventing typhoid fever. This vaccine was first used in the British army with great success. Tests showed 10 times as many cases among regiments which had not been treated as among those which had been treated. Fourteen deaths occurred among 7,000 unvaccinated soldiers, while no deaths occurred among the inoculated soldiers, 9,000 in number.

3. Tuberculosis: Its Nature, Prevention, and Control

567. Tuberculosis. — This disease in its destructiveness equals smallpox, diphtheria, typhoid fever, cancer, diabetes (dī′ă-bē′tēz), appendicitis (ă-pĕn′dĭ-sī′tĭs), and spinal meningitis put together. More than 500,000 people now have it in the United States and at that rate more than 5,000,000 persons now living in this country will die of it.

Tuberculosis is a disease of civilization. It occurs in different parts of the body, but the commonest form, that discussed here, occurs in the lungs and is known as *consumption.* It is common where people live in homes built closely together and improperly lighted, heated, and ventilated. Savage tribes know little of the disease until they come into contact with white men or begin to live in closed houses. Prevent unhealthy living conditions and the disease rarely appears.

568. How Tuberculosis Germs Cause Disease. — Persons afflicted with tuberculosis are continually coughing up sputum from the throat and lungs. This sputum is loaded with broken-down lung tissue which has been hardened by consumption bacteria. If a patient spits this sputum upon the ground or sidewalk, it slowly dries and sets free the bacteria or germs which cause the disease. Dust particles covered with these dried germs are carried about by the wind. When

some of them enter the nose or throat of a weak-lunged person, the result may be and often is a new case of tuberculosis. Again, tubercular patients, when coughing or sneezing, spread a spray containing myriads of the germs.

569. Tubercular Foods. — Investigation has shown that many cattle contract tuberculosis through the sputum of infected persons who have thoughtlessly spit on the grass or other food of the cattle.

Consequently, milk, butter, and cheese are often tuberculosis germ carriers, as was shown in Washington, D. C., where nearly 6% of all milk tested was infected with these germs, while 17% of the cans examined had them in abundance.

570. Cure of Tuberculosis. — The cure of incipient (just starting) tuberculosis is so simple that it seems almost foolish to suggest it. It simply consists of (1) fresh air (day and night); (2) plenty of sleep and rest; (3) good nourishing food; and (4) sunlight. In securing these conditions you set up factors which make war upon tuberculosis germs and destroy them. Can you tell how each factor helps in killing the germs?

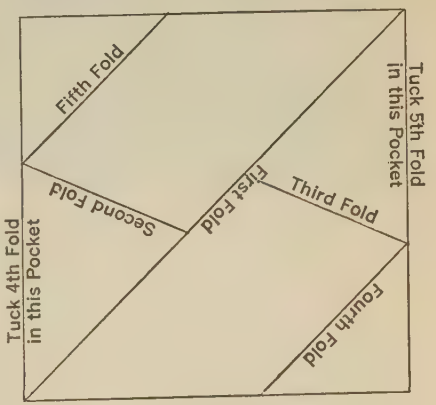


FIGURE 334. — HOW TO MAKE A PAPER DRINKING CUP.

Make a cup like this from a sheet of writing paper. What is the advantage of this cup?

In some localities, notably in Switzerland, patients are encouraged to exercise with arms and legs bare, even in the snow, the cold air and bright sunlight stimulating the skin and killing the germs. Another excellent help is to expose the chest to the direct rays of the sun for a definite period each

day. Bacteria cannot stand the direct white light rays. Of course, the body should not be chilled.

Signs marked " No spitting " are common now in public buildings and on public conveyances. Explain. Besides spitting, a common source of infection is the public drinking cup. This has been abolished in many states by law. Proper substitutes are paper cups similiar to those furnished

Trudeau Sanatorium.

FIGURE 335. — PART OF THE TRUDEAU SANATORIUM FOR CONSUMPTIVES AT SARANAC LAKE, NEW YORK.

Here persons who show symptoms of tuberculosis are made well at very low expense — simply their cost of keeping.

by railroads to their patrons. They can be purchased in many places for a penny. Or better, one can carry his own cup or can make one from a piece of stiff paper 7 inches square. Study Figure 334 and learn now how to make one.

571. Sanatoriums and Society. — Many cities now own municipal sanatoriums where tubercular cases are treated. At Otisville, N. Y., is one owned by New York City. At Mt. McGregor, N. Y., the Metropolitan Life Insurance Company maintains one for its employees and policy holders. Private enterprise and benefactions have been the means of building

many of these institutions all over the country. One of these of much note is the Trudeau (trū-dō′) Sanatorium at Saranac Lake, N. Y., built by Dr. Trudeau, himself once a consumptive patient, and his friends. This sanatorium is a monument to the people of the country who believe in helping others less fortunate than themselves (Fig. 335).

Organizations such as the Red Cross, the American Association for the Study and Prevention of Tuberculosis, and many others are all doing a noble work in combating the disease. As a result of all these activities since the year 1880, the rate of deaths from this cause in the United States has dropped more than 50%. It rests in the hands of the community and its health officers to determine whether within 30 years this disease can be completely driven out. Some men say that this is possible.

4. Insects as Enemies of the Community

572. Insects and Disease. — Five thousand American soldiers died of typhoid during the Spanish American War, and we now know that most of these deaths were due to typhoid flies. It is estimated that the annual financial loss in this country from typhoid alone is over $350,000,000, and the fly is responsible for most of it. It is also estimated that 90% of the loss in lives and money could be eliminated by proper community measures (Key Picture 23). Some cities require all manure piles to be treated with borax and then watered. This kills the eggs and larvae. Traps for catching flies are used on the streets in some communities. This helps, but it does not remove the source of the flies.

573. The Mosquito Menace. — The Anopheles mosquito carries the animal parasite which causes malaria, one of the most widespread diseases to-day. Its prevention, like that of yellow fever, is largely brought about by extermination of the mosquito. It greatly lowers the efficiency of all people who contract it. Study Key Picture 23 and learn the more important parts of it.

5. Yellow Fever and Its Control

574. Yellow Fever. — The history of the discovery of the cause of yellow fever reads like a detective story. In 1878 there were 125,000 cases and 12,000 deaths in three states alone. In 1900, army surgeons were working on the disease in Havana, Cuba. The progress and results of their great experiment can best be understood by reading the biography on the opposite page and studying Figure 336.

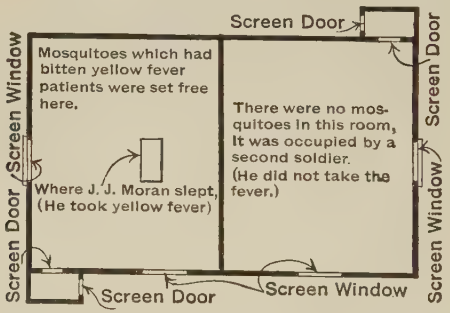

Screen Door
Screen Door
Screen Window
Mosquitoes which had bitten yellow fever patients were set free here.
There were no mosquitoes in this room, it was occupied by a second soldier. (He did not take the fever.)
Screen Door
Where J. J. Moran slept, (He took yellow fever)
Screen Window
Screen Door
Screen Door
Screen Window

Figure 336. — Diagram of the Yellow Fever Hut. Study this carefully and explain fully what it shows.

6. The Duty of the Community and the Individual

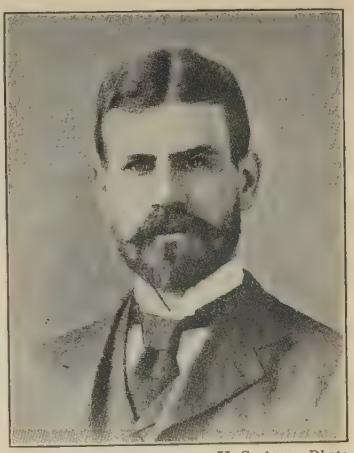
575. The Duty of Public Officials. — Too often neglect and politics interfere with a city's health conditions. In one community thus afflicted a physician had forgotten to report a contagious disease and 270 cases resulted from his neglect. Inefficient health officers are too often placed in office through political "pull." There can be no compromise between politics and the death rate. Health officers must be encouraged and backed up by public opinion. You are going to form the public opinion of the next thirty years. How can you help make your community healthy?

The duties of health officers should be to (1) collect facts; (2) control communicable diseases; (3) use all known

Dr. Jesse Lazear, Dr. Walter Reed, Dr. Carroll, and Others

A Yellow Fever Commission, headed by Dr. Walter Reed, began work in Cuba in 1900 to find out by experimentation the cause of yellow fever. Within six months it was proved that the bite of the female Aëdes mosquito causes the disease. Dr. Lazear, of the Commission, was bitten by a mosquito which had bitten a person suffering from the disease. Within a few days he contracted the disease and died. A memorial tablet attests his heroism by the following inscription:

"With more than the courage and devotion of a soldier, he risked and lost his life to show how a fearful pestilence is communicated and how its ravages may be prevented." Dr. Carroll was also stricken with the fever after being bitten.



U. S. Army Photo.

Jesse Lazear

To guard against possible error in the earlier experiment, two soldiers, John R. Kissenger and John J. Moran, volunteered for the test, "solely in the interest of humanity and in the cause of science" as they themselves said. Both contracted the disease. These tests proved that yellow fever is carried by the bite of a particular mosquito (Aëdes) and that contact with a person suffering from the disease will not cause one to contract it.

Dr. Reed's letter to his wife on December 31, 1900, an extract of which is here given, throws light upon the high purposes and character of these men who dared so much to serve the world. — "It has been permitted to me and my assistants to lift the impenetrable veil that has surrounded the causation of this most wonderful, dreadful pest of humanity and put it on a rational and scientific basis. I thank God that this has been accomplished during the latter days of the old century. The prayer that has been mine for twenty years that I might be permitted to alleviate human suffering has been granted."

The world needs such science and such scientists as these to make it a better and a more beautiful place in which to live!

methods to reduce infant mortality; (4) keep the community clean; (5) enforce all health ordinances; (6) control the fly and mosquito nuisance; (7) guarantee pure drinking water; and (8) properly remove all sewage. Can you tell why each of these points is important?

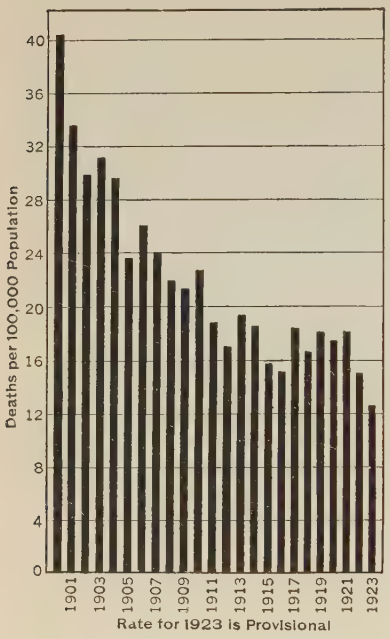


FIGURE 337. — DIPHTHERIA DEATH RATE IN THE UNITED STATES.

Study this graph and explain the story it tells.

Investigation has shown that in cities of from 30,000 to 50,000 inhabitants, but 27 cents is spent on the health of each person each year. This is holding the lives of people too cheaply. $1 per capita would be little enough to spend upon the very life of the community.

576. How You Can Help. — Many towns and cities prohibit spitting upon the sidewalk. You should be especially careful to obey such rules. The more dirt, the more disease! You can help reduce the amount of street cleaning now necessary, by seeing to it that you do not drop or scatter refuse or papers in the streets and that all refuse to be carried away is properly packed or tied. Your garbage pail should be kept covered and frequently cleaned. Refuse should not be allowed

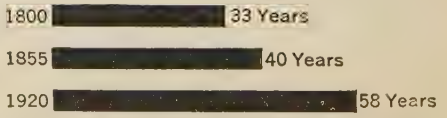


FIGURE 338. — PEOPLE ARE LIVING LONGER.

Can you give several reasons for this?

to litter up the yard, so that flies can breed. The sidewalks should be thoroughly swept every day. Every careless act means more work for someone and possibly sickness and death. Remember that the conservation of life gives a good name to your community. Its good name means its prosperity and makes it a place where decent people will like to live.

SUMMARY

The greatest *problem* of any *community* is to keep the people in a *state of good health*. *Impure foods*, *water*, and *air*, together with *insects* and other organisms, constantly endanger the health of the community.

Milk is a source of widespread *epidemics*. Strict *sanitary laws* to control the handling and storage of milk are very desirable. *Federal* and *city inspectors* must be constantly on the lookout for food law violations. Boards of Health must enforce *quarantine*. Epidemics must be prevented by *disinfection*, the use of *antitoxins*, *vaccines*, *tests*, etc.

Tuberculosis spreads in *milk*, *water*, the *air*, and *in meats*. It can be prevented by proper control of foods and the practice of proper habits of hygiene.

Insects cause epidemics, great suffering, and economic loss. Special methods of control must be used against the fly and mosquito in every community. Some of the greatest scientific discoveries have been made in connection with the carriers of disease.

Because epidemics may be far reaching in their effects it is the duty of public officials to place the health of the community first. It is the duty of every boy and girl to obey the health regulations of the community of which he and she are a part.

Remember that :

1. Epidemics of disease are more likely to occur in communities than in the country because of the ease with which disease germs may be carried to many people in milk, water, foods, etc.
2. Modern communities must constantly inspect and protect foods and the water supply if the health of these communities is to be kept at a high level.
3. Science has developed very definite and efficient methods for the control of community diseases and epidemics.

4. The skillful work of Jenner, Pasteur, Koch, Behring, Reed, Lazear, and others has been the chief cause of the modern control and reduction of such terrible diseases as tuberculosis, yellow fever, diphtheria, and hydrophobia.

5. The future progress and happiness of the world will depend upon the application of the discoveries of scientists to the prevention of disease and the education of everybody to the need of obeying the laws of hygiene and the ordinances of Boards of Health.

THOUGHT QUESTIONS

1. Why should streets be frequently sprinkled?
2. Of what advantage is it from a sanitary standpoint to have railroads oil their roadbeds?
3. Even in regions where ice is very plentiful, more people are using artificial ice to-day than ever before. Give a reason for this.
4. Compare the house fly and the mosquito as to life history, effects upon people, and means of controlling them.
5. In 1896 there were 1282 deaths from yellow fever in Havana, Cuba. In 1910 there were none. Account for this.
6. Discuss the work of Edward Jenner in its relation to the health of the community.
7. Why do many communities require the treatment of manure piles with borax or kerosene?
8. How does oil prevent the production of mosquitoes?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Adams. The Great American Fraud. American Medical Association.
Blount. Health: Public and Personal. Allyn and Bacon.
Brown. Health in Home and Town. Heath.
Boardhurst. Home and Community Hygiene. J. B. Lippincott Co.
Conn. Bacteria, Yeasts, and Molds in the Home. Ginn and Co.
Doane. Insects and Disease. Henry Holt and Co.
Howard. The House Fly. F. A. Stokes Co.
Hutchinson. Community Hygiene. Houghton Mifflin Co.
Jewett. Town and City. Ginn and Co.
Olsen. Pure Foods. Ginn and Co.
Ziegler and Jacquette. Our Community. J. C. Winston and Co.

PART VIII

THE WORK OF IMPROVING LIVING THINGS

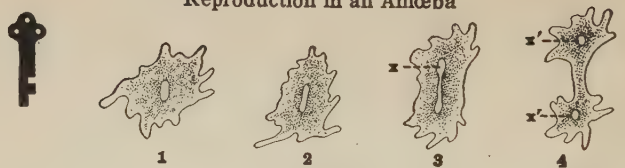
To know science is to know the truth no matter where it leads us.
— Wood

It is plain that the work of the world would not be carried on without life. Rivers would flow, winds would blow, rocks would crumble, but there would be no useful work done, if there were no living things present to profit by this work.

To carry on work the human engine must have food (fuel). To provide fuel, plants and animals must be grown. To insure a full supply of these plants and animals, man must study ways and means of improving them so that they shall become larger, better, and more abundant.

Man must see to it that he improves himself by improving his environment, by increasing his ability to resist disease, by developing his mind, and by reducing the number of weak people in the world. The Work of the World cannot be carried on by weaklings. If it is to be improved and made more efficient; if the world is to be a better and a happier place in which to spend one's life, there must be constant improvement in the bodily, mental, and moral equipment of men and women. We shall study together in the next chapter something of the way plants and animals came to be as they are now and some of the methods by which they are improved.

Reproduction in an Amœba

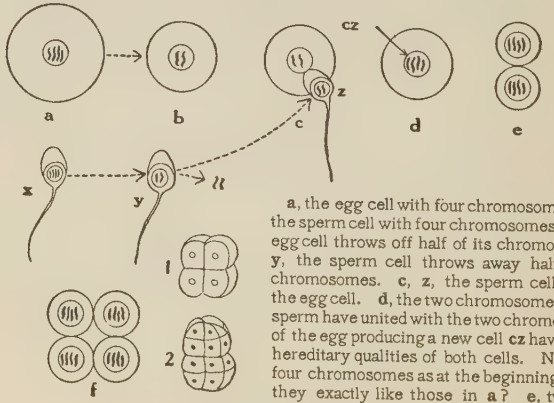


The animal simply divides, forming two animals. The new ones will be exactly like the parent. Why? Note, at **x** and **x'**, that the nucleus as well as the whole cell divides.

How New Cells Are Formed

What goes on inside the nucleus of a cell as it divides. At **a** are seen the chromosomes of the cell about to divide. These carry on the hereditary characters. At **b** is the centrosome which is supposed to control the division of the nucleus. At **c** the centrosome divides into two parts. At **d** the chromosomes are breaking up into small, short bodies, and the centrosomes have gone to the poles of the nucleus. At **e** the chromosomes have formed in line at the equator of the nucleus. At **f** they are splitting lengthwise and separating. At **g** they have passed to the centers of the two new cells to be formed and at **h** the wall separates them into two new cells.

Reproduction in Higher Plants and Animals



a, the egg cell with four chromosomes. **x**, the sperm cell with four chromosomes. **b**, the egg cell throws off half of its chromosomes. **y**, the sperm cell throws away half of its chromosomes. **c**, **z**, the sperm cell enters the egg cell. **d**, the two chromosomes of the sperm have united with the two chromosomes of the egg producing a new cell **cz** having the hereditary qualities of both cells. Note the four chromosomes as at the beginning. Are they exactly like those in **a**? **e**, two new cells are formed by cell division. **f**, four new cells are formed from the two cells. This process now goes on in **1** and **2**, forming tissues and organs until the whole animal or plant organism is formed.

KEY PICTURE 24. — HOW LIVING THINGS ARE PRODUCED.

CHAPTER XXIV

THE ORIGIN, CONSERVATION, AND IMPROVEMENT OF LIFE

A fire-mist and a planet,—
A crystal and a cell,—
A jellyfish and a saurian,
And caves where the cave-men dwell,
Then a sense of law and beauty,
And a face turned from the clod,—
Some call it Evolution,
And others call it God.

—*William Herbert Carruth.*

What do you know about life? Here we come to the last and in some ways the most important chapter of all. What will you take for your life? Do you know where life came from in the beginning? Do you know how new animals and plants get a start in life? Do you suppose that bees help flowers in any way when they visit these flowers? Are any two living things just alike? What is the advantage of this difference? Do you know why you look like your father or mother? Do you know how plants and animals are improved to-day? Do you think man can be improved? How? This is the most interesting chapter in the book.

Some Practical Questions :

1. How do bacteria and yeasts produce so many offspring and why do birds produce so few?
2. Name all the animals you can think of which produce their

young from eggs; by birth. Name some plants which produce others by "slips"; by buds; by seeds.

3. Why do people often speak of a boy as "a chip of the old block"?

4. How do people account for a "black sheep" in the family?

5. Why are people who live in the slums of a city more likely to commit crime than people who live in the best parts of a city?

6. How can we account for a "criminal class"?

Home Problem. — 1. Select a small plot in your garden and divide it into halves, each two by three feet. Plant in each plot the same number of pea seeds, say one dozen, and water one plot every third day and water the other plot once a week. Note the results after four weeks. Account for these results. Does environment affect the growth of plants?

2. Study the members of your own family. Note the differences between your father and mother as to color of eyes, hair, complexion, facial expression, and height. Note the characteristics of your brothers and sisters, — note how many resemble those of your mother and how many those of your father. Compare your own characteristics to those of your parents. Is the law of heredity here shown? Is the law of variation shown? Can you call yourself a variation? Why?

Field Problem. — 1. Select a small plot ten feet square in a vacant lot. Secure a specimen of every different kind of plant which grows in this plot. Does any one kind predominate over the others? If so, can you account for this? Do the various kinds seem to fight for the light? Is there a struggle going on here? Explain. Are the leaves arranged so as to shade each other or so as to get out of each other's shadows?

2. Study people as you pass them on the street. Do you note any different types of people? Can you call some intellectual and some dull-minded from the looks of them? Which type seems to be the more numerous? Do you note any with low foreheads, broad heads, and ears set far back on the head? What do you think will be the effect of the prevailing type you note upon the country 100 years from now?

1. Where Living Things Come From

577. The Origin of Living Things. — Your common observations teach you that all living things come from living things. Plants grow from seeds that grew on plants

the season before. Chicks hatch from eggs laid by a hen. Frogs come from tadpoles which in turn come from eggs laid by the mother frog and fertilized by the father frog. All life comes from life.

578. Cell Structure. — A close observation of a single cell under the microscope reveals a *cell wall* which incloses a bit of jelly-like substance called *protoplasm* containing a heavier body of protoplasm, the *nucleus* (see page 132). Within this nucleus is found a mass of irregularly shaped bodies called *chromosomes* (krō′mŏ-sōmz) (Key Picture 24), so called because they are bodies which take stains deeply. These chromosomes are now known to be of great importance in the life of all living things.

579. How New Living Things Are Produced. — Careful observation of an *amœba* or a *paramecium* (păr′ȧ-mē′shĭ-ŭm), two one-celled animals, will reveal the fact that new individuals are produced by the splitting or division of the original animal into two smaller animals. This method of producing new individuals is known as the *asexual* (ȧ-sĕk′shŭ-ăl) method, because there are no parents in the sense in which we think of parents (Key Picture 24). The parent cell simply becomes two cells by splitting in two. However, the chromosomes carry to each new animal the qualities of the old one.

But there is a method of reproduction in which the new individual does not look exactly like the original cell, because there are two cells involved in the reproduction, — there are two *parents* differing from each other. Each contributes something to the new individual. This is the method used by most higher plants and animals.

In this method of reproduction, the grown plant will produce different colored flowers from its parents because the qualities of both parents were mixed in it. A puppy may be spotted black and white though one parent was white and the other black. The new individual, then, resembles *both* parents in general, but is really different from each because it carries in its body the characteristics of

both. The chromosomes are responsible for this resemblance (Key Picture 24).

2. How Plants Produce Seeds

580. Flowers and Insects. — Watch a honey bee or bumble bee visit a flower. These insects seem to make a business of visiting flowers. They alight on certain kinds of flowers at

Figure 339. — Three Kinds of Bees: Worker, Queen, and Drone.
The workers are always busy during the day gathering nectar and pollen. In this way flowers are pollinated. How is the bee adapted for this work?

exactly the same place at each visit. They visit but one kind of flower while you observe them and they seem to be getting something from each flower they visit. Closer observation will show that the hairy body of the bee is literally covered with a yellowish powder or dust-like substance called *pollen* (pŏl′ĕn). There must be some reason for these business-like visits (Fig. 339). What is the reason?

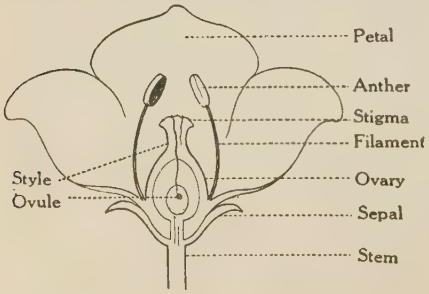


Figure 340A. — A Typical Flower in Section.
Learn all the parts and know their functions.

Laboratory Exercise. — Carefully examine a single part of each different group of like parts in

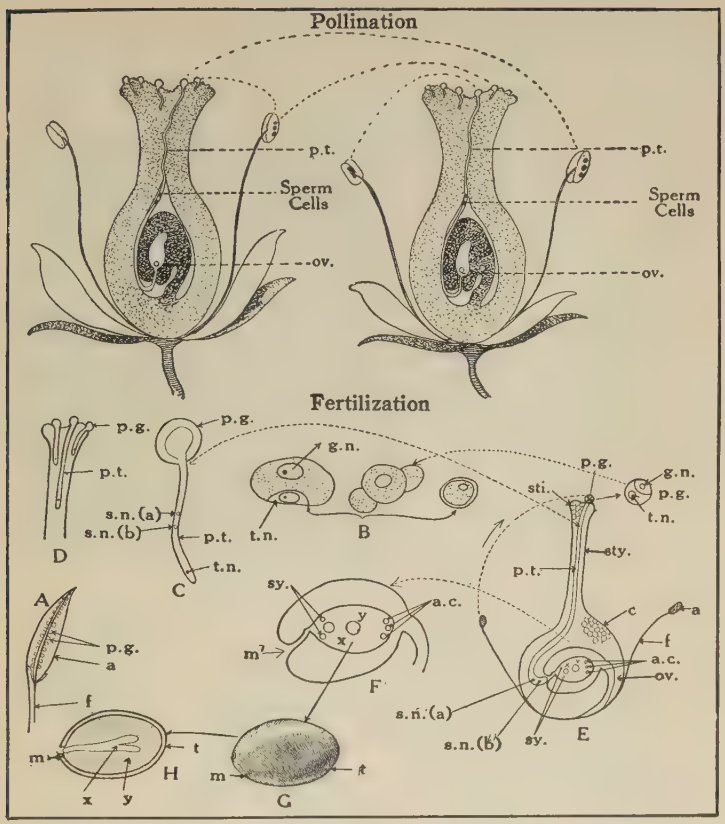


FIGURE 340B. — POLLINATION AND FERTILIZATION OF A TYPICAL FLOWER.

A. Stamen Opened. **a**, anther; **p.g.**, pollen grains; **f**, filament.

B. Types of Pollen Grain. **t.n.**, tube nucleus; **g.n.**, generative nucleus.

C. Pollen Grain and Tube. **s.n.(a)**, sperm nucleus; **s.n.(b)**, sperm nucleus; **t.n.**, tube nucleus; **p.t.**, pollen tube; **p.g.** pollen grain.

D. Stigma. **p.g.**, pollen grain; **p.t.**, pollen tube.

E. Section of Pistil Showing Process of Fertilization. **p.g.**, pollen grain; **sti.**, stigma; **sty.**, style; **c**, cell structure of pistil; **sy.**, synergids, which help in fertilization; **a.c.**, antipodal cells which disappear; **ov.**, ovary.

F. An Ovule in Section. **m.**, micropyle.

G. A Seed from the Outside. **t**, testa (covering).

H. Interior of a Seed. **x**, embryo; **y**, endosperm.

a gladiolus or tulip flower (Fig. 340a). Note the arrangement of parts in these groups. The outer parts are called *sepals* (sē′pălz) and together form the *calyx* (kā′lĭks). This protects the flower in the bud. The next set of parts is called the *corolla* (kŏ-rŏl′*a*) and is composed of *petals* (pĕt′ălz). They attract insects. Remember this: The little knobbed, slender bodies are called *stamens* (stā′mĕnz). The top of the stamen is called the *anther* (ăn′thĕr) and grows the *pollen*, a powder found on the anther. Examine some of this dust under the microscope and draw three grains. The stalk is called the *filament*. The center part of the flower is called the *pistil* (pĭs′tĭl). The top of the pistil is called the *stigma*. When a pollen grain of the right variety falls on the stigma, it sends a tiny *tube* down through the *style* (Fig. 340a) into the *ovary* and on into the *ovule*. A male cell finds its way out of the tube into the ovule where it fertilizes the egg cell. The *ovule* then becomes a seed. Flowers whose stigmas use pollen produced by their own anthers are *self-pollinated;* those which use only pollen from other flowers are *cross-pollinated* (Fig. 340b).

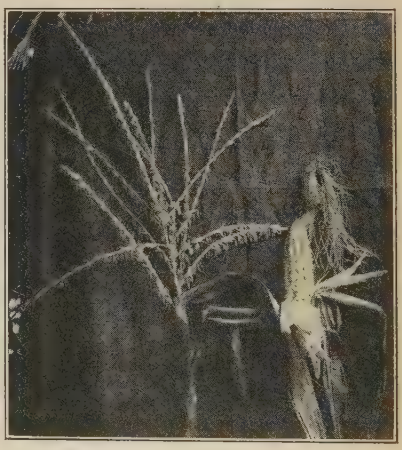


FIGURE 341. — THE CORN FLOWER.
This is a cross-pollinated flower.

581. The Work of the Pollen and Ovules. — The bee visits the flower for *nectar* (nĕk′tȧr), but its hairy body carries the pollen from flower to flower, either to the *stigma* of the same flower, or to stigmas of other flowers on the same plant or to *stigmas* of flowers on a different plant. This process is called *pollination*. Study Figure 340b and tell what happens after pollination.

582. The Embryo. — On opening a bean seed, a little plant, completely formed but inactive, is found there. This little plant or *embryo* (ĕm′brĭ-ō) was formed from the fertilized egg inside the ovule. The egg was the result of pollination.

FIGURE 342. — STEPS IN THE LIFE HISTORY OF THE FROG.

1. Fertilized egg. **2.** Two-celled stage. **3.** Four-celled stage. **4.** Eight-celled stage. **5.** Cell structure of a later stage. **6.** Formation of tissues. **7.** Development of embryo. **8.** Tadpole. **9.** Appearance of hind legs. **10.** Appearance of front legs. **11.** Loss of tail and gills, — fully developed frog (with lungs). Tell the story pictured here.

583. Development of Animals. — The reproduction of animals is surprisingly like that of plants. The mother frog produces within her body great numbers of unfertilized eggs, which she lays in the water in early spring. The male frog places upon these eggs what corresponds to the pollen grains of the flower; namely, sperm cells, and thus fertilizes them. The sperm cells unite with the egg cells forming a new cell. This new cell soon begins to divide into two cells, then into four, eight, sixteen, and on up, just as in the flower embryo. Finally, a young tadpole is formed from this many-celled embryo. The tadpole develops hind legs, then its front legs, loses its tail and gills, and becomes our old acquaintance, the frog (Fig. 342).

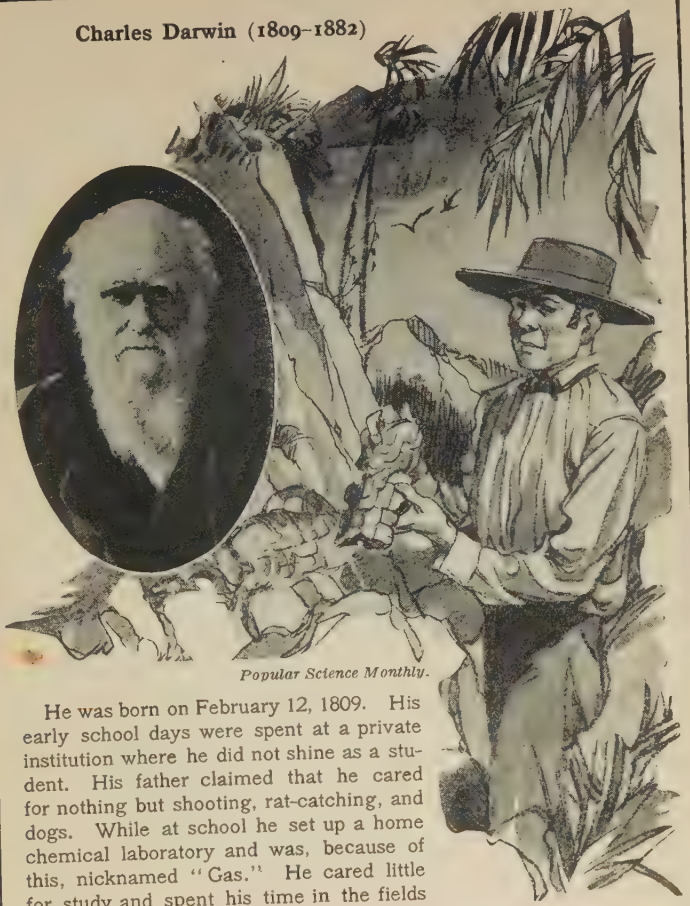
3. Why All Living Things Are Unlike

584. Heredity and Variation. — We all know that frogs taken as a class look very much alike. The young look like their parents, due to the handing down of the characteristics of one generation to another. This handing-down process is called *heredity* (hē-rĕd′ĭ-tĭ).

But a careful observer will notice that all frogs are not alike. Living conditions (that is, the character of the environment) cause one frog to differ from another in certain physical features. They vary in size, color, and even in shape. Again, in plants, some sweet peas are white while others are red or purple; some short, others tall. They vary among themselves, even though they are of the same general kind. This tendency to differ among plants and animals of the same kind is called *variation* (vā′rĭ-ā′shŭn) (Figs. 343 and 344).

585. How Charles Darwin Studied Science. — Charles Darwin, a great English scientist, made a special study of variation and heredity, gathering facts and data about them on his trip around the world in the ship *Beagle*, in the year 1836. He saw many new plants, new birds, and new insects everywhere. Moreover he saw resemblances between

Charles Darwin (1809–1882)



Popular Science Monthly.

He was born on February 12, 1809. His early school days were spent at a private institution where he did not shine as a student. His father claimed that he cared for nothing but shooting, rat-catching, and dogs. While at school he set up a home chemical laboratory and was, because of this, nicknamed "Gas." He cared little for study and spent his time in the fields gathering flowers and insects.

In 1831 he set sail with a South American expedition and at once became a zoologist, botanist, and geologist. He made many new discoveries concerning fossil remains. His studies showed him that there were gradual changes in living things and he explained these changes by "natural selection" and "the survival of the fittest." After twenty-seven years of study to prove his theory, in 1859 he published his book entitled "The Origin of Species," now regarded as one of the greatest books of the nineteenth century. Darwin did not try to explain the problem of creation, but he did try to explain the method of work of the Creator.

Brooklyn Botanic Garden and Geo. M. Reed.

FIGURE 343. — VARIATIONS IN SORGHUM.

The two plants at the extreme left are the parents. All the rest are the children. All these forms are alike; all are different. Explain this.

many of them, though in many cases like forms were separated by a continent. He also saw that men could breed different kinds of pigeons. The question came to him: How do wild animals change? What influences act upon them? What laws control their development? He asked himself a long list of such questions. He pondered upon these problems for twenty-seven years and finally attempted to explain them in his wonderful book "Origin of Species." He tried to show that Nature selected those species which were best fitted to live, and slowly but surely killed off those not well adapted to living. This theory he called *Natural Selection;* it is based on five factors. He saw that:

(1) There is an *overproduction* in nature. Of the millions of seeds produced by plants, only a few ever grow into plants. The codfish lays 20,000,000 eggs yearly, yet codfish do not greatly increase.

(2) There is a severe *competition* for food among living things.

(3) No two living things are *exactly alike.*

FIGURE 344. — VARIATIONS IN BEETLES.

Note how the markings vary here. Yet all had the same parents.

(4) Differences among living things seem to help them *to fit into their environment.*

(5) Those that survive because they fit their environment carry on these valuable qualities to their offspring through *heredity.*

586. How the Five Factors Work. — In the early days of this country wolves were so thick that the struggle for food became acute and many never grew up into matured wolves. But enough survived to run in packs and become a constant

FIGURE 345. — DEER AND WOLVES: HOW THE FIVE FACTORS WORK.

1. A large number of wolves means many mouths to feed. **2.** A struggle among the wolves in catching the deer follows. The best deer get away, the weakest perish; the fleetest wolves catch the deer, the slower wolves starve. **3.** Variation among the wolves and deer made some strong and some weak. **4.** The stronger seem best fitted to survive. **5.** Those that survive produce their own kind and the race grows stronger.

menace to other animals including man. Suppose that a pack of wolves begins to follow a herd of deer. Now study Figure 345 and explain how the five factors work.

587. Mutants. — In 1885 Professor Hugo de Vries (dē vrēs′), a Dutch botanist, found a wonderful primrose plant. Among its descendants were some plants with many flowers, and some with few flowers. Some had small flowers, others had large flowers. The seeds of each of these different

flowers when planted produced plants exactly like their parents. These plants bred true. Such sudden changes in plant structures Dr. de Vries called *mutants* (mū'tănts) (Fig. 346). These mutants can produce other organisms like themselves. As a result of this important discovery it is permissible to say that through mutations new kinds of living things have arisen. By mutations great changes in plant and animal structures are possible in a much shorter time than Darwin's explanation would require.

FIGURE 346. — MUTANTS.

These beetles are marked variations from their parents. They will breed true. They are mutants. The cause of mutants is not fully known. Extreme conditions during breeding time tend to produce them.

4. How Plants and Animals Are Improved

588. Practical Application of the Laws of Heredity. — In 1862 a Mr. Fultz of Philadelphia found three heads of wheat without chaff, as he was walking through a field. He at once recognized the importance of his discovery, though the term "mutant" had not at that time been coined. He planted these three grains of wheat and produced a strain of beardless wheat which is now known the world over as Fultz wheat. This shows how mutants can be used to enrich our agriculture.

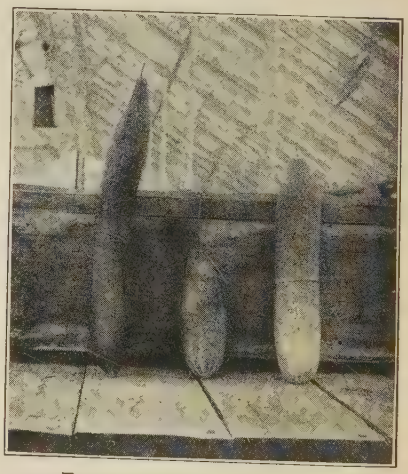


FIGURE 347A. — CUCUMBERS.

The father and mother are at the left. The offspring is at the right. Was anything gained here by the crossing? Explain.

While passing through a cotton field in South Carolina, Dr. Webber, a plant breeder, discovered a cotton plant with bolls hav-

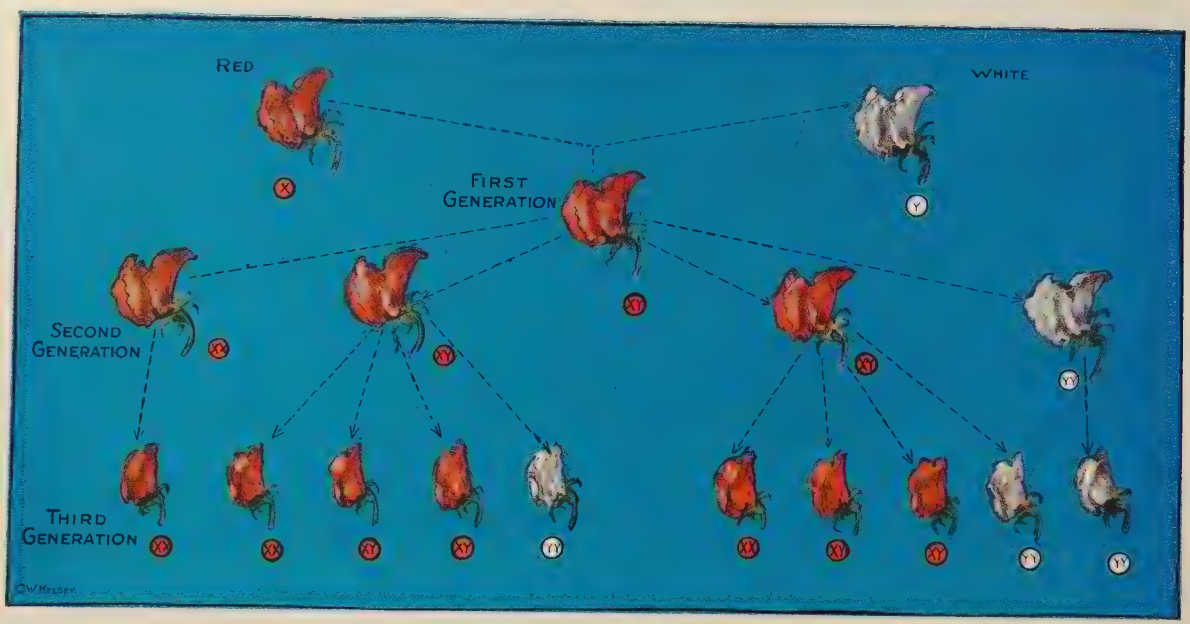
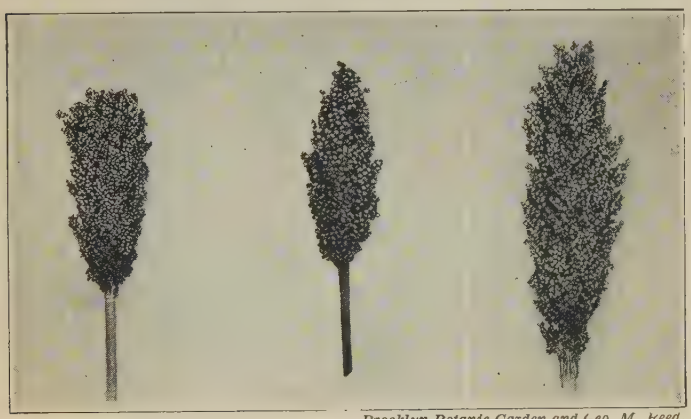


PLATE VI.—GREGOR MENDEL'S LAW.

Study carefully section 589, with footnote, and Figure 348. Then study the above picture and answer these questions: Why does not the whiteness of the white flower appear in XY the offspring of X and Y (1st Gen.)? Why will three out of every four of XY's offspring (2d Gen.) be red and the fourth white (if XY is self-pollinated)? Why will XX produce nothing but pure reds if self-pollinated? Why will YY produce nothing but YYs? What happens when the XYs are self-pollinated (3d Gen.)? Explain. After studying this picture, explain Mendel's three laws.

ing extremely long cotton threads or staples. He removed the plant, planted its seeds, and the result was a new kind of cotton now called Columbia cotton.

Luther Burbank when a boy in high school, while passing through a potato field on his way to school one day, discovered several seed balls on a remarkably developed potato plant. He secured these



Brooklyn Botanic Garden and Geo. M. Reed.

FIGURE 347B. — SORGHUM HEADS.

The parents are at the left. The offspring is at the right. Does it resemble its parents? Explain.

balls when ripe, planted the seeds, and produced the now famous Burbank potato, which has added millions upon millions to the wealth of this country.

Soon after the Revolutionary war a farmer noticed in his flock of sheep one with very short front legs and a long back. The offspring of this sheep showed the same traits. The result was a new breed of sheep called the Ancon, — a *mutant*. The hornless cow is also a mutant.

589. Gregor Mendel and His Work. — It was discovered by Gregor Mendel, an Austrian monk, that heredity works under very definite laws. He proved this by experiments upon garden peas in the garden of the monastery. As a result of his labors he worked out some very clear prin-

ciples of heredity which were lost to the world from about 1866 to 1900, but rediscovered at that time.[1]

590. The Use of Mendel's Laws by Some Practical Breeders. — (1) In the winter of 1905 Dr. Charles E. Saunders put away, in a paper packet no larger than an envelope, a small handful of wheat grains which he had grown during the previous summer. He had obtained these grains by crossing mid-Europe Red Fife with an impure wheat called Red Calcutta, imported from India into Canada some years earlier. He produced a medley of wheats, nearly 500 in all, and from this large group he selected one, now known as the Marquis wheat. Thirteen years after the first crop of this wheat — all placed in a small packet — the total crop reached 250,000,000 bushels.

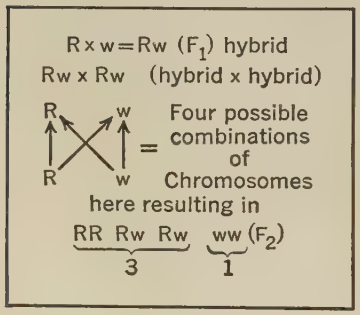


FIGURE 348. — MENDEL'S LAW.

Compare this diagram with Plate VI. The letters **R** and **w** refer to the red and the white flowers of the plate, but they may serve as symbols for any other types of plants or animals being studied. **R** is capitalized to denote the dominant trait. (F_1) denotes the first generation; (F_2), the second.

(2) In animal breeding also much progress has been made. "Jolly Lassie," a Jersey cow, produced in one year the

[1] Mendel found by experiments on garden pea flowers that single traits or characters (color of flower and seed, etc.) are carried down to the next generation without being mixed or lost. He called this fact the Law of Unit Characters. When Mendel crossed two plants having opposite characters, he called the offspring *hybrids*. Hybrids contain traits of both parents, one of a pair of opposite traits being always hidden, however. The character which appeared Mendel called *dominant*. The other character he called *recessive*. This condition he called the Law of Dominance. If hybrids were crossed, the characters separated out again, in the ratio of three pure and mixed dominants to one pure recessive. This fact Mendel called the Law of Segregation. Finally, a pure dominant always produces a pure dominant and a pure recessive always produces a pure recessive. Why? Study Figure 348 and Plate VI.

Popular Science Monthly.

Luther Burbank (1849–1926)

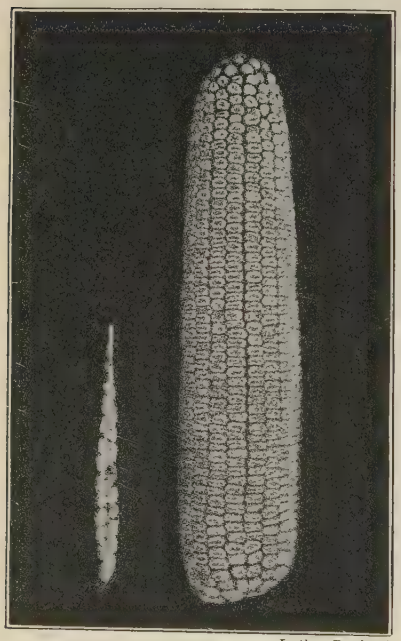
Luther Burbank was born with a love of living things. As a small child, it is said, he was accustomed to carry a potted plant about with him and if he dropped it, cried until provided with another. While a lad in high school, he discovered a mutant potato which became famous as the Burbank potato and added millions to the wealth of the farmers of this country.

Moving to California when a young man, he began the experimental work which has made his name known throughout the world. He possessed a remarkable skill in growing and selecting mutants and in crossing, selecting, and improving existing varieties of plants. He put to practical use the Mendelian laws of inheritance and thus produced many new and useful kinds of plants, flowers, and fruits.

The thornless cactus, the plumcot, the loganberry, the Climax plum, the white blackberry, and the Shasta daisy are some of his wonderful contributions to our food and ornamental plants. This man did as much, if not more, than any other in using the forces and laws of nature to improve plants useful to man. He was rightly called the "wizard" of the plant kingdom.

astonishing amount of 1,141.28 pounds of butter fat. Another Jersey, "Madeline," produced 20,624 pounds of milk. These cows were the result of selection and proper crossing.

591. The Work of Luther Burbank. — The work of this great practical breeder deserves special mention. The writer visited Mr. Burbank's experimental farm at Santa Rosa, California, in 1915 and there saw some of these things for himself: gladiolus flowers growing all about the stem, though usually they grow along only one side; verbenas with the odor of violets; walnut trees that grew seven feet in one year, though their usual rate of growth is but a fraction of an inch a year; white blackberries; and enormous daisies. These are just a few of Burbank's wonderful creations.



Luther Burbank.

FIGURE 349A. — THE ORIGIN OF CORN.

Luther Burbank bred this corn back to its ancestor (left), a grass called teosinte. Man has produced through breeding the ear at the right.

Mr. Burbank developed corn that towered 18 feet into the air and produced 32 ears of corn upon each stalk. This was done by the practical application of the Mendelian Laws.

Poppy seeds were planted by thousands and a very few pleasing varieties produced by the tremendous struggle for existence were selected. Then these were crossed and a further selection made. This process went on for several years until he grew poppies

with flowers ten inches across. He produced a blue poppy; a new fruit called a plumcot, — a cross between an apricot and a plum; an immense daisy called the Shasta daisy, six inches across, by crossing the New England field daisy with the Japanese daisy; a flower which is everlasting and now used in decorating ladies' hats; and a chestnut tree which produces chestnuts eighteen months after its seed is placed in the ground. The cactus of Arizona has been rid of its thorns by proper breeding and is now valuable food for cattle. Mr. Burbank's methods are well summed up in this statement:[1]

Luther Burbank.

FIGURE 349B. — CORN IMPROVEMENT.

Luther Burbank made a better Yellow Bantam corn. How? What was gained here?

Abundant, well-balanced nourishment and thorough culture of plants and animals will always produce good results in holding any variety up to its best possibilities. But only by the constant selection of the *best* can any race ever be improved. With these two lines of action *combined*, all the best qualities of any type are brought forth and fixed — and the field for improvement is limitless.

Luther Burbank

[1] This statement was sent by Mr. Burbank for use in this book.

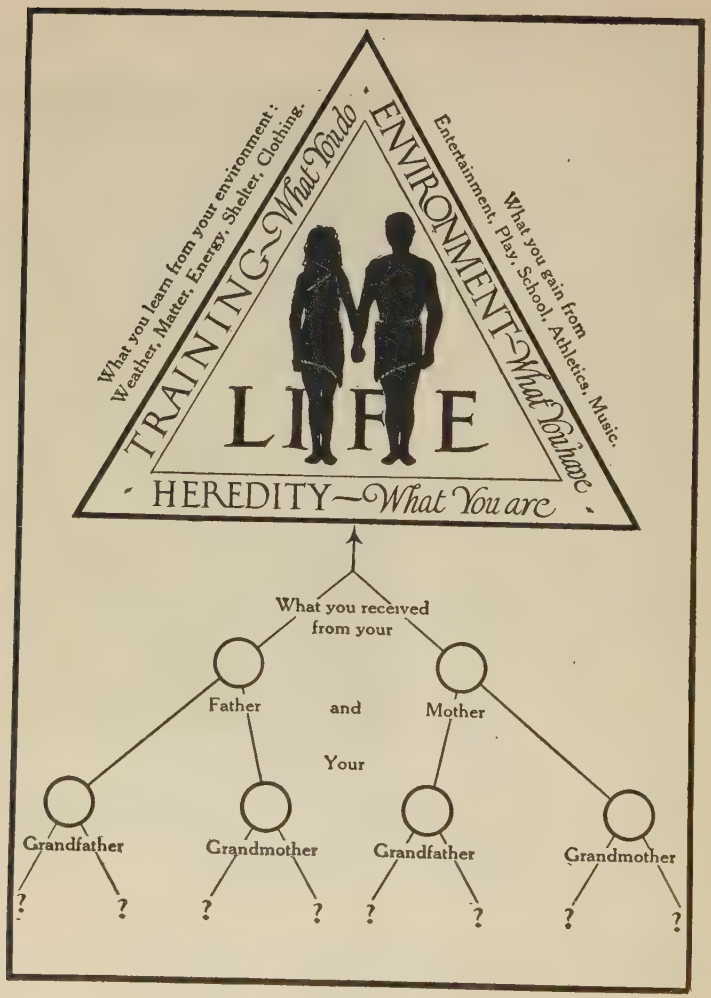


FIGURE 350. — WHAT YOU DO, HAVE, AND ARE.

Which side of the triangle do you think has the greatest influence on your life? How much of your hereditary qualities did you receive from each great-grandparent?

5. How Heredity Works in Man

592. How Man Has Progressed. — The story of how man has gradually developed from a savage to a civilized man is a long one. He no doubt progressed through the influence of three factors. (1) *Heredity*, which gave him at birth some capacity to do things. Some men have more natural capacity than others. All can be trained. (2) *Environment*, which helped him to learn things. Man could

Figure 351. — Heredity in Man.

Five generations are here shown. Follow the resemblances from the baby to its great-great-grandfather. Why does not the baby more closely resemble the oldest man? Why does it resemble him at all? Explain the picture fully.

not help learning by coming into constant contact with the things about him. (3) *Education*, which is a method of training the mind, helped him to think clearly, draw correct conclusions, and judge wisely.

593. Mendel's Laws and Human Heredity. — Such families as the Nam, Kallikak, and Jukes, the Hill Folk, and the Ishmaelites, in which immoral, feeble-minded, pauper, vagrant, and drunken traits appeared with regularity through several generations, give ample proof of the working of

Mendel's law. In the Kallikak family it was found that out of 480 descendants traced, 143 were feeble-minded. All received this feeble-mindedness from their mother.

6. How Man Can Improve Himself

594. Eugenics. — But there is another side of the picture which we must not overlook. There are 35 normal-minded persons to every feeble-minded person in the country.

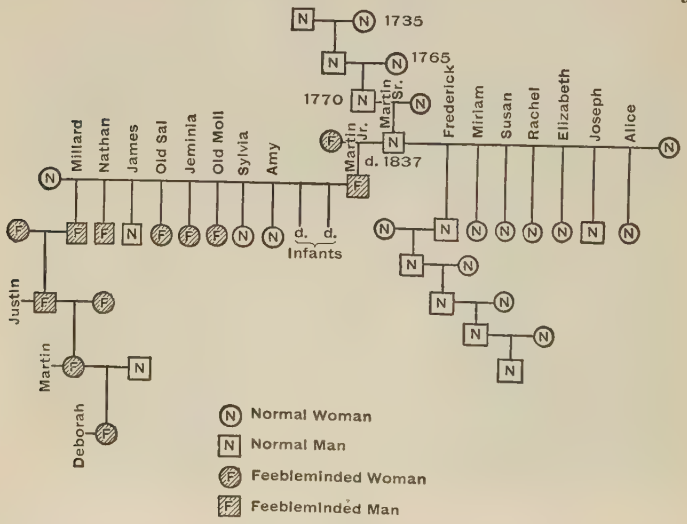


Figure 352A. — The Kallikak Family.

Trace the ancestors on both sides through both mothers. Explain the differences. How many defective people do you find?

The future well-being of the nation depends upon these normal-minded people. To encourage the recognition of this fact the science of *eugenics* has developed, which is the science of improving the human race by better heredity through a wiser and better selection of fathers and mothers. Chromosomes tell the story. "Blood will tell."

595. The Jonathan Edwards Family. — A study of the chart and questions will give the details of the development of this wonderful family. The important thing to observe

is that among the members of this family, numbering 1394, there have been:

13 college presidents
100 lawyers and ministers
75 army officers
60 authors
60 physicians
1 Vice-President of the United States
3 United States senators
30 judges
295 college graduates not included in the foregoing
16 railroad presidents
Several governors
Not one pauper
Not one convicted of a crime

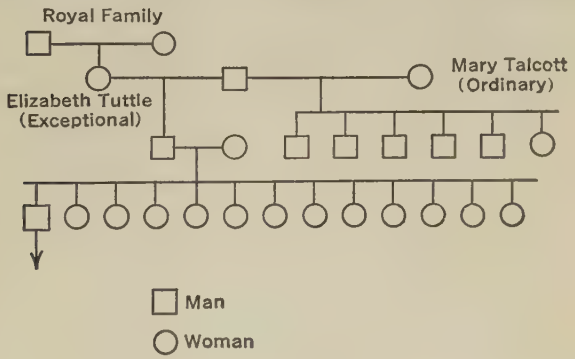


FIGURE 352B. — THE JONATHAN EDWARDS FAMILY.

The left-hand line produced all the exceptional people listed above. The right-hand line produced no noted persons. Explain this.

596. Euthenics. — Improvement of heredity is closely linked with improvement of environment. Individuals from a good environment stand a better chance of transmitting good traits to a succeeding generation than do individuals from a poor environment. The science of improvement of environment is called *euthenics*.

The effect of alcohol as a factor of environment is revealed in the following table:

	No. Children	Died in Infancy	Defective	Normal
Drinking families . . .	57	12	36	9
Abstaining families . . .	61	5	6	50

Removing alcohol from the environment of people who live where they are encouraged to drink is a means of bettering the race. A progressive community will provide the right kind of environmental factors for its citizens. Each family is responsible to the next generation for its health and it can best fulfill its duty by being clean inside and out.

FIGURE 353. — A POOR ENVIRONMENT.
Think of this spot as a playground for babies and children! What are the dangers of such yards?

597. Three Steps in Race Improvement. — (1) The first step in race improvement is *cleanliness.*

(2) A second step is to insure *proper hours for labor.* Bodies run down by overwork are fit subjects for disease. Diseased parents cannot give their best qualities to their children. The remedy for this is shorter hours of work with opportunity for more rest, leisure, and recreation. Read the following article:

The recent report of the Federal Children's Bureau shows some very clear results of a study of the causes of death of 23,000 babies

in eight cities. Among the Jews there is a death rate of 53 in every 1000 as against 200 out of every 1000 among the Portuguese. The Portuguese mothers work at hard labor in the factories far more than do the Jewish mothers. The death rate among those babies whose mothers worked away from home was 176 in every 1000, while it was 98 among those babies whose mothers simply did their own housework.

This story shows how long hours of labor for mothers affect the next generation. Improvement of the race demands less work of a hard nature for mothers.

Again, hundreds of children have been working and in some cases now work in canning factories 14 hours a day, while young boys act as helpers in glass factories, coal mines, and silk and cotton mills. They do not get enough rest, their growth is retarded, and they never fully develop, mentally or physically.

Ewing Galloway.

FIGURE 354. — A GOOD ENVIRONMENT.

Every baby, every boy, and every girl have a right to grow up in such an environment. Why do they not enjoy that right? Do what you can to secure for yourself such a place in which to live.

(3) A third step is *proper environment for babies.* In the United States to-day nearly 300,000 babies die every year before they are one year old. What is the cause of this? Poor environment, ignorance on the part of the mother, and poor care. Children are blessed or cursed by their environment. In 1892, 1000 babies under the age of five years died in a certain city. People at that time used milk from any and all sources. In 1904 but 500 died, though

the population had increased by 30,000. The milk supply had changed. Clean milk was demanded by the Board of Health. The babies thrived and fewer died. This was due to betterment of the environment.

598. Race Improvement and the Work of the World. — The work of the world will always depend upon strong, sturdy people. But the fewer the sick and helpless, the less burden for the well. We should bend every effort toward the rearing and education of a race that can enjoy the best that life has to offer. This, after all, is the real world's work.

The astronomer looks up and out; the biologist looks down and in. One uses the telescope; the other uses the microscope. Both see the same thing and that is ***law.*** — Wood.

SUMMARY

The invention and improvement of the *microscope* made possible the discovery that all living things are composed of *cells*. Cells are composed of *protoplasm*, *nucleus*, and *chromosomes*. These latter bodies are now known to carry the qualities of the parents to the offspring.

Some animals are produced by the splitting of the parent. This is the *asexual* method. Higher plants and animals produce *sperms* and *eggs* which fuse into one cell which grows into a new individual.

Flowers are visited by insects because of *nectar* and *pollen* stored in them. This pollen is carried from flower to flower and results first in *pollination* and then in *fertilization*. The final product is a *seed*. This seed will contain the qualities of both parents.

From the *embryo* in the seed the young plant *germinates* and soon becomes an adult capable of producing others like itself.

Charles Darwin observed that plants and animals vary much in appearance. He concluded that these *variations* were valuable to them. He noticed that living things with certain variations lived while others died and that many living things seems to have developed from less complex forms. This development, he suggested, was brought about by five factors working at all times. Hugo de Vries, on the other hand, claims that new forms of life come about by sudden changes or *mutations*.

Fultz wheat, *Columbia cotton*, *Ancon sheep*, etc., are all *mutants*. *Marquis wheat* and many other cereals have been produced through the use of *Mendel's Laws* of *Unit Characters*, of *Dominance*, and of

Segregation. *Luther Burbank* used these laws to produce hundreds of new plants.

Man himself has progressed through heredity and environment. Heredity in man works according to the Mendelian laws. This sometimes results in noted good and bad families. The importance of belonging to a good family is clearly seen.

The improvement of the human race is the science of *eugenics.* *Euthenics* is the improvement of the environment of man. Good environment strengthens the germ cells. Proper environment for mothers and children and proper working conditions for fathers will insure a better coming generation.

Remember that :

1. We now know that life can come only from life.
2. Heredity carries down the characteristics of parents to offspring. Variations in living things are caused by the union of the eggs and sperms of parents which are not exactly alike.
3. Heredity and variations can account for all the different kinds of animals and plants on the earth to-day through the process of gradual change.
4. The food of the world will depend in the future upon improved methods of producing better and more animals and plants.
5. Man has progressed from savagery to civilization by using the factors of his environment.
6. Heredity, training, and environment have been and are the most important factors in the progress of man.
7. Good and bad traits can be carried down from parents to offspring by heredity.
8. The improvement of the environment of everybody will be one of the greatest factors in the physical, mental, and moral improvement of the human race.

THOUGHT QUESTIONS

1. Suppose that one yeast plant can reproduce every half hour for 12 hours. How many offspring will there be then? Can you tell why this would probably not happen?
2. How can reproduction take place among plants without the use of seed? How is this of value to the farmer? to the seedsman?
3. Some city people think that it is easy to make a fortune by moving to the country and raising chickens. Are they right?
4. A pair of quail devoured over 1500 rose beetles in a single day. What has this to do with the struggle for existence?

5. A cod fish lays millions of eggs each year. Is there any value in overproduction?

6. Why is it not possible for birds to produce many young?

7. What is the great advantage of a mutant from the standpoint of man?

8. How can Mendel's laws be of value to the farmer? to the gardener?

9. Secure several ears of corn of different kinds. Why do they differ so much? Explain.

10. There are over 1,500,000,000 human beings in the world, yet no two are just alike. Explain why this is so.

11. Why is artificial selection much easier among plants than among animals?

12. Consumption is not hereditary. Explain, then, why children of consumptives are more likely to have this disease than other people.

13. Some one has said that a child should be trained before he is born. What is the meaning of this statement?

BOOKS OF SPECIAL VALUE AS AIDS IN THE STUDY OF THIS CHAPTER

Bailey. Plant Breeding. The Macmillan Co.
Boyle. Prehistoric Man. Little, Brown and Co.
Burbank. His Methods and Discoveries. Luther Burbank Society.
Burkett. Our Forerunners. Henry Holt and Co.
Clodd. Childhood of the World. The Macmillan Co.
Conklin. Heredity and Environment. Princeton Univ. Press.
Davenport. Heredity in Relation to Eugenics. Henry Holt and Co.
Estabrook. The Jukes in 1915. Carnegie Institution Pub. No. 216, 1916.
Goddard. The Kallikak Family. The Macmillan Co.
Harwood. New Creations in Plant Life. The Macmillan Co.
Goldsmith. The Laws of Life. Richard Badger. Boston.
Gates. Heredity and Eugenics. The Macmillan Co.
Jewett. The Next Generation. Ginn and Co.
Kummer. First Days of Man. George H. Doran Co.
Kummer. First Days of Knowledge. George H. Doran Co.
Lovell. The Flower and the Bee. Charles Scribner's Sons.
McColeb. "Happy": The Life of a Bee. Harper and Bros.
Richards. Euthenics. Whitcomb.
Waterlos. The Story of Ab, — The Cave Man. Doubleday, Page and Co.

APPENDIX

SPECIAL PROBLEMS

These special problems are designed to supplement and complete the work assigned you by your teacher from the various chapters of the text. To do as many of these *extra* problems as possible will be an excellent test of your growth as a young scientist.

Chapter I

1. Make a study of the way a duck, a horse, a giraffe, a lion, a seal, and a maple tree are fitted to their environments. Report.

2. Have one of your classmates place ten objects on a desk before the class. In thirty seconds see how many of these things you can observe and remember. Have the objects covered and then name as many as you can.

3. Have some of the ten above-mentioned objects removed and the others rearranged. Try the same experiment as before.

4. As you pass a store window observe as many things as you can in one minute and then write them from memory. Later in the day try again at the same window allowing the same time. Have you increased your list? Explain how this happened.

Chapter II

1. Study the way in which Thomas Edison or Luther Burbank made some one of his great discoveries and report.

2. Study the history of a great invention used in your home and report upon it (Welsbach burner, sewing machine, or the like).

3. Let some member of the class make a collection of pictures showing various steps in the improvement of the automobile from the earliest to the latest models and put them on display before the class. Then let each pupil write a story telling about the improvements in each step. Explain why this year's model of any car could not have been made in 1900.

Make a similar collection of pictures of the airplane. Follow the plan outlined above. Do airplanes differ among themselves more than automobiles? Explain.

4. Outline for yourself an original problem to be worked out in your own home. Collect materials for this problem, confer with your teacher about it, work it out, taking careful notes as you proceed, and make a final report to your class.

Chapter III

1. Examine a meat chopper. Discover all the simple machines in it and make a report upon them.
2. Examine a washing machine, a cream separator, or a bicycle. Discover all the simple machines which make up each and report upon them.
3. Study a derrick or a steam shovel and identify all the simple machines of which it is composed. Make a report on your findings.
4. Make a study of an automobile and determine where the most friction occurs in its operation. How is this friction reduced? Report.
5. Make a study of an egg beater to determine the simple machines which compose it.
6. Use a set of scales or steelyards. Check up on the weights of food bought at the grocery and at the butcher shop. Verify the law of machines on this machine.
7. If a boy weighing 100 pounds sits three feet from the fulcrum of a seesaw, how far from the fulcrum must a stone weighing 75 pounds be placed so that the boy can easily seesaw?
8. A man who can use a force of 150 pounds wants to raise a 300-pound barrel of sugar into a wagon three feet from the ground. How long must the board be up which he is to roll the barrel?

Chapter IV

1. Study the action of a barograph for three days and report upon your observations.
2. Determine how an automatic ink well works. Report on this.
3. Determine how a self-filling fountain pen works. Explain.
4. Report on the lives and works of Galileo and Torricelli.
5. Secure from a vacuum cleaner manufacturer a descriptive catalog, study it, and explain to the class the way this make of machine is built and the principle upon which it works.
6. Study and report upon the construction and work of an insect sprayer.
7. With suggestions from your teacher make a model caisson and show how it works.

Chapter V

1. Learn how best to improve the ventilation of your sleeping room.
2. Make a study of ventilating devices and construct one for use in your home.
3. Study and report on the construction, principle, and work of the ventilating system of some public building (school).
4. Make a report upon the various methods used to remove dust from the presence of workers in mills and factories.
5. Make a study of the Health Code of some city to find out what ordinances are in effect which bear upon the use of air by persons.
6. Determine the effect of pure and impure air upon the ability to do good mental work.

Chapter VI

1. Clean the waste-pipes of your sink or laundry tubs, using lye or ammonia and hot water. Report on your results.
2. Clean a waste-pipe or the refrigerator trap in your home.
3. Report on how pure water is secured in New York City or in Los Angeles, California.
4. Report on a model water-supply system for a farmhouse. Send to your State Department of Agriculture for material on this subject.
5. Report on the values of different methods of cooking foods.

Chapter VII

1. Construct a model community water supply system showing fountains, house supply, fire supply, etc. and demonstrate it.
2. Determine where the drinking water supply of your city comes from and how it gets into the city water reservoir.
3. Determine how your city purifies its water supply.
4. Determine the water pressure upon a square inch of surface at the bottom of a tank containing one cubic foot of water. Upon 10 cubic feet of water.
5. Determine the conditions which led to the building of the Roosevelt or some other storage dam.
6. Make a report on the methods used to reclaim waste lands.
7. Secure pictures and drawings of the principal water storage dams in the country and try to explain the construction of each.

Chapter VIII

1. A study of a steam-heating system.

Suggestions: Compare a typical steam-heating plant with a hot-air furnace. Note how they are different and how alike.

Determine where the water comes from and where it goes in the furnace; where it is heated; where the steam is formed; where the steam goes; what becomes of it in the rooms; and how and in what form it gets back to the steam boiler again. Find out how the steam heats the rooms.

Study figures in catalogs and compare with your own plant.

Take care of your steam plant for a week with the idea of understanding its principle, keeping an even heat, and saving fuel. Report in full to your class.

2. A study of a hot-water heating plant.
3. Study and report upon an electric range or furnace.
4. Report upon the coal industry in the United States.
5. Report upon a visit to the gas works in your town.
6. Report on the coke industry.
7. Report upon the refining of crude oils.
8. Report on the manufacture of charcoal.
9. Report upon the oil industry.

Chapter IX

1. Make a study of light distribution in your home with an idea of improving it.

Suggestions: Using a 40-watt bulb, a Welsbach burner, or a good kerosene lamp, try the following tests for reading:

a. Leave the light exposed at about one foot above the table. Place a book in front of you on the table about 18 inches from your eyes and from the light. Note the effect of the light upon your eyes. Note also its effect upon the print of the book.

b. Place a dark green shade upon the light. Make the same tests as before and record the results.

c. Invert the shade so that the light is thrown upon the ceiling. Make the same tests again and record the results.

d. Now use a translucent cream-colored shade in both positions. Test as before and record results.

e. Test again in the same way with white, brown, blue, and pink shades. Record results. What do you consider the best kind of light distribution? Give reasons for your answer.

f. Make the same tests with the same shades for the general lighting of your room. What is the best method of light distribution for this purpose? Give your reasons. Is it possible to get a light distribution which can be used both for reading and lighting? Explain.

2. Study the proper methods of light installation and light distribution in a new house.

3. Report on the kinds and uses of fuses.
4. Report on glass manufacture.

Chapter X

1. Trace the wiring of the bell system in your home. Note how the circuit is kept open and the reasons for it. Note how it is closed and the result.
2. Learn how to repair your electric doorbells.
3. Learn how to clean and renew the parts of a wet cell.
4. Draw a plan of electric bell wiring circuit in your home. Bring the drawing to class and demonstrate it.
5. Set up a St. Louis motor,[1] and work it. Describe just how the motor runs.
6. Work out an original problem in which you show how electricity can cause motion.
7. Take a simple motor apart and reassemble it. Determine the exact use of each part and how you put it in place.
8. Make a magnet by heating a steel knitting needle and plunging it when red hot into cold water. Next, stroke it with a permanent magnet and mount it in a small box and use it as a compass.

Chapter XI

1. Make a list of all the sources of energy and the forms of energy used in the manufacturing plants in your city after following the directions below:

(*a*) Visit three industrial plants (no matter how small) in your city and determine the principal form of energy used in each.

(*b*) Determine in each case the source of the energy used.

(*c*) Determine if each form of energy used can be traced to a common source. Explain this fully.

(*d*) Determine which form of energy used is the most economical.

(*e*) Determine which form of energy used is most efficient.

(*f*) Discover if air is used in any of the plants visited either in compressed form or at atmospheric pressure. Note how this air is used and why it is used.

(*g*) Observe, in the plants you visit, just how the energy used is applied to the machinery and how it is transferred and transformed.

(*h*) Note the obstacles which interfere with the easy working of the machinery in these factories. Suggest changes for getting rid of them.

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[1] This is a simple type of motor which can be purchased from any general laboratory supply house. It can be easily taken apart and reassembled.

(*i*) Note the simple machines and observe how they are used.

(*j*) Become acquainted with the compound machines used and determine all the simple machines in each of the several compound machines you observe.

(*k*) Find out how much work one of the compound machines does as compared to what could be done by hand.

(*l*) Determine in general how the factory you visit and its product is connected with other factories and products.

Chapter XII A

1. Study a model of a steam locomotive. Locate the drive wheels, the connecting rods, the steam chest, the cylinders, the pistons, the wheel flanges, the point of connection of the connecting rods and the drive wheels, and the inlet and exhaust valves. Determine the use of each.

Now keeping your model in mind, study a typical locomotive wherever opportunity affords you the chance and try to find out how each part works.

2. Procure a catalog of a four-cylinder automobile. Study the diagrams of the engine construction, making note of the following parts: Cylinders, pistons, connecting rods, shaft, intake and exhaust valves, spark plugs, and valve lifters. Determine how the valve lifters are moved. Next study an automobile itself, locating as far as possible all the above parts. Determine the location of the cooling system, the oiling system,the ignition system, and exhaust apparatus. Find out how each works. What prevents the engine becoming set on "dead center"? Locate the timing device and determine its use.

3. Make a study of several railroad bridges. Note the materials used in each and the size of the structures used. Which type do you think best and why?

Chapter XII B

1. Make a toy sailboat, rig it, and sail it. Write up your experiences while making the boat, telling of your difficulties and the way you overcame them. Explain the principle of the sailboat. Explain its buoyancy and tell why it floats.

2. Report your experiences to the class in learning the processes necessary to row a boat (backing, turning, handling of oars so as to get most power, rowing in rough water, etc.).

3. Explain to the class the principle of sailing, including a discussion of tacking, steering, the use of the centerboard, and the difficulties to be overcome in becoming a good sailor.

4. Discuss the handling of a motor boat. Explain to the class the principle of the engine, its care, starting, stopping, and control of its speed. Explain the purpose and advantages of the lines of the boat. Tell the class the difficulties to be overcome in running a motor boat.

Chapter XII C

1. Make a fire balloon and cause it to rise.

2. Secure some light tough paper (colored, if possible) and some very slender bamboo sticks. Make the frame of a box kite. Cover with the paper by use of tough glue. Study carefully the proper place to attach the guide string. Careful experiment is the only way to solve this problem. Fly the kite. Study the way it behaves and try to solve the principle of its flight. Report your conclusions to the class.

3. Secure a copy of Collin's "The Boys' Book of Model Aëroplanes," published by Century Co., and after selecting the simplest model in the book try to collect the proper materials and construct a model plane according to the directions. Try out your plane. Report to your class the difficulties you met and had to overcome in building your plane. Demonstrate your plane and explain its principle.

Chapter XIII

1. Secure a few smooth boards and fasten together with cleats, as shown in the diagram. Paint an outline of a house as seen from

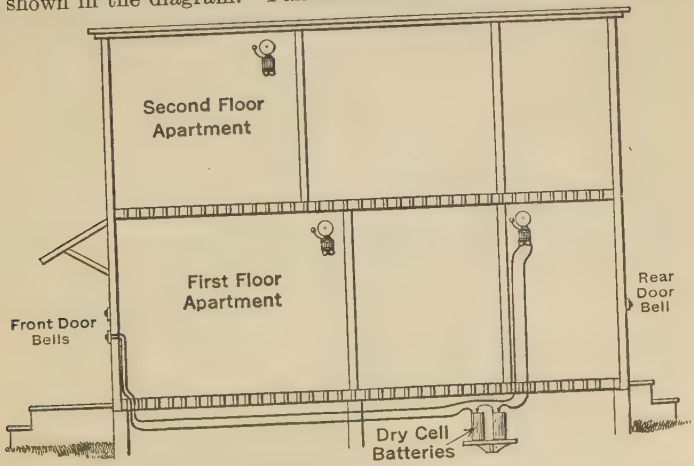

FIGURE 355. — BELL WIRING IN A HOUSE.

the side with front and rear doors. Secure at least two electric bells with wiring enough to connect them up in several circuits and either purchase a battery of dry cells or use the sal ammoniac wet cell you may have on hand.

The above is a two-family house as seen from the side. Three bells are indicated. The connection between the front doorbell button, the kitchen bell, and the battery in the cellar are shown. Fasten the bell and button in place on your board and connect the wires correctly. Try the bell. Explain how and why the bell rings. Now fasten the other two bells in place and work out the following problems of wiring.

a. One bell with two push buttons, one at the front and one at the back door.

b. One bell and one push button at the back door.

c. Two bells and two push buttons, each button to ring one bell.

d. Three bells and three push buttons, each button to ring one bell.

Remember that there is to be one complete circuit in every problem. Where more than one bell is in the circuit it is suggested that two dry cells be used.

2. Collect the proper materials and set up a wireless plant. Learn the international or the continental code. Report on the way you set up the apparatus, the difficulties you met and overcame, and emphasize the principle of the wireless.

3. Collect the materials for a crystal radio set. Set it up under the direction of some wireless expert or from a book of instructions for simple sets. Report to the class upon the way you succeeded in overcoming your difficulties.

Chapter XIV

1. Show by good arguments how the 20th Century Limited is propelled by the sun.

2. Secure a full account of the solar eclipse of January 24, 1925, and give a report on the chief features of this event.

3. Look up at least three stories of the constellations and report on the relations of these groups of stars to the gods of mythology.

4. Make clay or putty models of the sun, earth, and moon in proper proportions and distances from each other. Show how these bodies act in relation to one another.

5. Make a study of the moon for one month, charting its appearance every other evening. Note the time of its rising every night and be able to account for its rising schedule.

Chapter XV

1. Study the book of the local weather bureau.
2. Test some of the common weather predictors. Examples: the leech, frog, and spider as barometers; a halo around the moon; and falling smoke. Add others.
3. Make a record of the daily air pressures covering one full week and plot a graph to show these pressures. Extend this record to two weeks; to a month. Note the weather each day.
4. Compare this barometric record with your weather record and note if they seem to be related. Explain this relationship if it exists.
5. Make a hygrometer and use it to determine the relative humidity.
6. Make a daily humidity record for a week. Plot a graph to show this record. Extend this record for two weeks; for a month.
7. Compare temperature, barometer, and humidity graphs covering the same period and look for any relationships.
8. Make a rain gauge and use it to determine the extent of rainfall during three successive storms.

Chapter XVI

1. Draw a plan of a cold frame and list the materials needed to complete the work.

a. Select location for the cold frame and follow plans for making it as outlined in Farmer's Bulletin, No. 255, U. S. Dept. of Agriculture, Washington, D. C.

b. Grow in this frame some lettuce, cabbage, and tomato plants, raising them from the seed.

c. Report on the progress of the work. Explain the principles of the cold frame. Transplant these plants to your vegetable garden.

2. Plant, care for, and harvest the vegetables of your home garden.
3. Learn to know various kinds of insects which may come to your garden.
4. Learn how to control the insect pests of the garden.

Chapter XVII

1. Select a farm, plot it, determining what crops you would plant and where you would plant them. Explain your decisions.
2. Determine the effects of heat, light, air, and moisture upon the growth and development of a selected kind of green plant (corn).

3. Make a detailed study of the life histories of three typical farm crops (corn, wheat, potatoes).

4. Make a detailed study of the life histories of three typical weeds on the farm (mustard, yarrow, Canada hawkweed, etc.). Determine the best method of controlling them. Try out your method.

5. Study the life history and the best methods of exterminating three typical insect pests on the farm (squash bug, corn borer, codling moth, etc.).

6. Learn by experimenting the best methods of grafting one kind of tree to another. Determine the advantages of grafting.

7. Learn how to transplant a tree or vine and take care of it, reporting to the class on the details of your work.

8. Form a corn or agricultural club for the purpose of studying and putting into practice new methods of producing better crops on a given area of land.

9. Secure from the state agricultural department booklets on the care of fruit trees and practice the methods upon some selected trees, noting the results and reporting them to the class.

10. Write an article on the life history and achievements of Luther Burbank.

Chapter XVIII

1. Determine the nutrients in some of the common foods used in your home.

2. Make a list of the foods used in your home for one day, determine as nearly as you can the amount of each used, and the cost of each at the prevailing prices. Get the total for the day. For example, if a brother from two to six years of age needs 1200 while you need 2400 calories, then the amount for him would be one-half yours and the cost in proportion.

Determine whether your food is costing you too much. Get the averages of any ten members of the class and find out what the average excess in cost is for these ten families per day; per week and for the year. Discuss these results with your father and mother and see what they think about it. Try to correct the condition, if possible.

Chapter XIX

1. Carefully study the parts of the alimentary canal in a mounted dissected toad or frog. Copy and label all the parts in your Science Discovery Book.

2. Study the human alimentary tract or canal in a manikin or chart. Copy and label all parts. Compare with a frog tract and identify similar parts by use of common labels.

3. Note the teeth of a dog, cat, horse, cow, rabbit, guinea pig, or other animal. Do they differ among themselves? Do the teeth in each animal differ from the others? Observe the food each kind of animal eats and see if you can find a reason for the difference in dentition (arrangement of the teeth).

4. Study human dentition either by observing a human skull or your own teeth. Note the number of kinds of teeth you find, the total number of teeth, and the total number of each kind. Now see if you can find in your own mouth examples of every kind of tooth found in a dog, rabbit, and horse. Does this give you any light on the kinds of food the human engine needs? Explain.

Chapter XX

1. Make a study of your own actions and determine how many of them are reflex during one day. Indicate the special value of each action to your body.

2. Make a study of the habits you use each day. List them. Determine in a general way how much time these habits save you in the course of one day. What would happen if you could form no habits?

3. Decide to form some habit which you know will be beneficial to you. Note how you start, how you progress, and how long it takes you to get good results.

4. Make a study of the formation of habits in a baby brother or sister and report to the class.

5. Study habit formation in a pet kitten or dog. Tell how you have taught a trick to a pet and the results you obtained.

Chapter XXI

1. Visit a milk station and observe the methods of handling milk. Criticize these methods. Make clear the proper methods in use.

2. Visit and report on the methods of handling bread and other foods in a bakery; in a restaurant, or hotel.

3. Make a test of the bacterial content of some raw and some pasteurized milk.

4. Make a study and report upon the work in fermentation of Louis Pasteur.

5. Observe in your home the effects of yeast on sugar and bread dough.

6. Make a study of the tubercles of clover plants and report on the work of bacteria in connection with these plants.

7. Compare the keeping qualities of pasteurized and unpasteurized milk.

8. Determine in your home the effects of disinfectants upon the growth of bacteria.

9. Visit and report on a canning factory, noting the methods used in preparing, sterilizing, and sealing the foods in cans.

Chapter XXII

1. Determine how vaccines and antitoxins were discovered and how they are prepared and used.

2. Learn how to disinfect a room properly.

3. Learn how to dress a small wound properly.

4. Make a study of the life history of three disease-carrying insects and how they may best be controlled or exterminated.

5. Make a study of the best methods of exterminating crawling insects in the home.

6. Determine the best methods of exterminating rats and mice

7. Collect several samples of cloth, determine their composition by proper tests, and ascertain their value as clothing.

8. Study the best methods of controlling clothes moths.

9. List the diseases which your department of health requires to be quarantined.

10. Learn the methods of your town or city in controlling the purity of the foods sold in its markets. Report to the class on what you find.

Chapter XXIII

1. Make a survey of the fly or mosquito menace in your community. (*a*) Formulate your problem. (*b*) Outline details of how you will go to work to solve your problem. (*c*) Make note of your experiences in studying the details of the problem. (*d*) Make suggestions for improvement of conditions. (*e*) Make suggestions as to proper methods of beginning a campaign for eliminating the mosquito menace. (*f*) Report your work to the class.

2. Study and report on the health ordinances of your community, giving the reason for each law.

3. Visit and report on the methods used in a city filtration plant.

4. Determine how borax acts upon the larval stage of the house fly. Account for these effects.

5. Make a survey of your community to determine possible sources of epidemics.

Chapter XXIV

1. Collect some frog's eggs and placing them in the right conditions for development, watch their progress, making drawings of them from time to time and reporting on them. Finally write out a complete life history of the frog.

2. Make a study of the methods of reproduction in insects, birds, frogs, fishes, mammals, and flowering plants and report to the class a comparison of all methods studied.

3. Select several plants which you know can be multiplied by cuttings and experiment with them in your garden. Write out a complete report of your work.

4. What seems to be the advantage of overproduction in plants and animals? Make a study of several plants growing in vacant lots and discover the average number of seeds produced by six plants of each kind. Discover, if you can, whether or not the number of seeds determines how many plants grow in the lot each year.

5. Select some weed in a vacant lot and note the variations in the number of its petals in twenty of its flowers or in the number of its seeds. What is the average? How could this average be increased? Could it be increased indefinitely? Explain. What do breeders try to develop in plants and animals?

6. Make a careful study of your own environment. Compare it with those having a better or a worse one. Make a list of the things you might do to change it for the better.

List the things that might be done to change poor environments in your community so that they will be regarded as good ones. Would this be a community work or an individual work? Explain.

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